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Field Guide To Pests of Managed Forests in British Columbia

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FOREWORD

BY DR. R. DEBOO, R.P.F.

Management activities in British Columbia's diverse and very valuable forests have been framed by distinct and interrelated sets of economic, social and environmental factors. These conditions change in complexity east to west and south to north across this province's 25 million hectares of operable Crown and private forest lands. Multiple-use policies, biogeoclimatic considerations, special environmental concerns, changing demographics, community dependencies and expectations, and the basic need to support a strong and dynamic forest industry are some of the factors which shape management regimes here. In all quadrants of British Columbia, management plans are now in place and activities underway to achieve objectives as dictated by these factors.

One of the most challenging requirements for forest managers and allied specialists is the implementation of effective, economical and environmentally acceptable treatments to protect and enhance this large and variable resource. This program, often referred to as **Integrated Forest Protection**, must span the full term of the forest rotation. It must offer input at the planning and prescriptive stages. It must apply to small trees and young stands. It must ensure the survival and continued growth of trees and stands approaching rotation age.

There are five recognized categories or groupings of damaging agents to consider when initiating integrated protection:

1) Forest insect pests
2) Forest disease organisms
3) Non-human vertebrate pests
4) Competing and undesirable vegetation
5) Forest fires

The first edition of this "Field Guide to Pests of Managed Forests" gives examples from the first three of these groups - insects, diseases and vertebrates. Also included is a brief discussion of some abiotic factors, such as severe weather conditions, which may damage or kill trees in managed stands.

Knowledge about all of these factors may, for the average individual working in forestry, be impossible or unnecessary. However, basic awareness of some key signs, symptoms and potential impacts as presented in this guide should be considered a basic requirement for most personnel. Characteristic feeding galleries, tooth marks, conks, caterpillars, and expressions of injury to tree trunk, foliage and roots will signal likely causes of many problems. Time, patience and perseverance will allow the interested individual to develop this basic ability to contribute.

This guide has been especially prepared to (1) assist the generalist and to (2) encourage individuals to learn some of the factors affecting forest health. The guide is also designed for inclusion in field kits, cruiser vests, and glove compartments of forestry vehicles. Take it with you and use it, please.

INTRODUCTION

Each year the forests of British Columbia are damaged by a multitude of pests and abiotic agents. Subsequent growth loss and mortality have a negative affect on the practice of forest management and the economic potential of our forests. As a result, experts from the British Columbia Ministry of Forests, Forestry Canada, industry, universities and other organizations endeavor to better understand the biology, and reduce the effects of forest pests and damaging abiotic agents. However, it is the person in the field, often with limited knowledge or experience in pest identification, who first encounters these damaging pests and agents.

The purpose of this field guide is to assist field personnel, working within the forest industry of British Columbia, in the identification of injurious insects, diseases, and other agents. However, our forests and the damaging agents which affect them are very diverse. This guide is not intended to replace the specialized training required to become proficient in diagnosing all causes of damage to our forests; it was designed to assist the user in recognizing general pest groups and important insect pest and disease species, common abiotic agents, and the damage these cause.

The selection of individual pests and abiotic agents, for inclusion in this field guide, was based on three criteria:

1. The level of damage historically caused to forests in British Columbia. Pests or agents were included only if they have caused significant losses on several occasions;
2. The frequency with which the pest or abiotic agent was likely to be encountered in the field. Pests or agents were included only if they are commonly encountered and cause some damage;
3. The age of the forest predominantly affected by the pest or agent. Specific pests or agents were included only if they primarily affect forests younger than rotation age. Therefore, bark beetles and decay fungi were excluded since they primarily attack mature to overmature forests.

Notes on the biology of a pest were included only if these were considered to be useful for identification purposes. In addition, pest management strategies, which are continually changing, were not addressed in any detail. However, references addressing biology and control of specific species and agents were included wherever possible. Common names for insect pests and diseases were obtained from Nomenclatura Insectorum Canadensium (P. Benoit. 1985. Canadian Forestry Service, Laurentian Forest Research Centre. 5th ed.) and Common Names for Tree Diseases in the Western United States and Western Canada (F.G. Hawksworth, R. L. Gilbertson, and G.W. Wallis. 1985. Supplement to the Proceedings of the 32'nd Annual Western International Forest Disease Work Conference), respectively.

HOW TO USE THIS FIELD GUIDE

Not all factors which may affect the health of British Columbia's managed forests were included in this field guide - only those most likely to be encountered or to cause damage have been listed here. Thus, it is very important to recognize that expert advice and confirmation may be required. As well, if damage appears to be widespread or increasing, special surveys may be necessary. The following steps are suggested for confirming pest identification:

(1) Use the keys, photos and descriptions in this guide to make tentative identification.

(2) Collect specimens (damage, pest) and forward promptly to local specialist (regional entomologist, pathologist, research officer) with the B.C. Forest Service or other suitable local government agency or educational institution.

(3) If identification cannot be confirmed locally, request assistance from the Forest Insect and Disease Survey of Forestry Canada in Victoria. The procedure has been outlined in the Protection Manual (Vol. II, Chap. 2) of the Ministry of Forests and in the "Specimen Collection and Shipment Section" of this guide.

(4) In the case of new or rare specimens, identification or confirmation from specialists outside British Columbia may be required.

This field guide is divided into four main sections: insect pests, diseases, abiotic injuries and animal pests affecting managed forests in British Columbia. Under each section, damaging agents are grouped together based on the part of the host tree which is primarily attacked. Agents within these groups are arranged in alphabetical order according to common name. Each agent has relevant text and photographs that describe the most obvious identifying features. General keys to the four main sections and more specific keys to individual insects, diseases, abiotic injuries and animal pests precede the appropriate sections. In addition, a host-pest index, a section on collection and shipment of samples, and a glossary, follow the pest descriptions. The host-pest index is especially useful for verifying the specific insects and diseases affecting each area of a particular tree species since this index is arranged according to portion of host affected.

All keys have been designed to be used in the same manner as a flow chart. When attempting to determine the exact source of damage encountered in the field, first use the general keys for direction to the appropriate insect pest, disease, abiotic factor or animal pest species key. Next, use the more specific keys to identify the particular damaging agent involved. Only brief descriptions of distinguishing features are found in the keys. Therefore, decide which of the listed features best describe the signs and symptoms encountered in the field and select the corresponding pathway. Start at the top of each key and proceed along the most appropriate pathways until the specific damaging agent has been identified. Each insect species, disease, abiotic factor and animal species in the keys has a corresponding page number for its descriptive text and photographs under the sections that follow. The tentative identification reached using the keys should always be carefully checked by reading the more complete descriptions in the text.

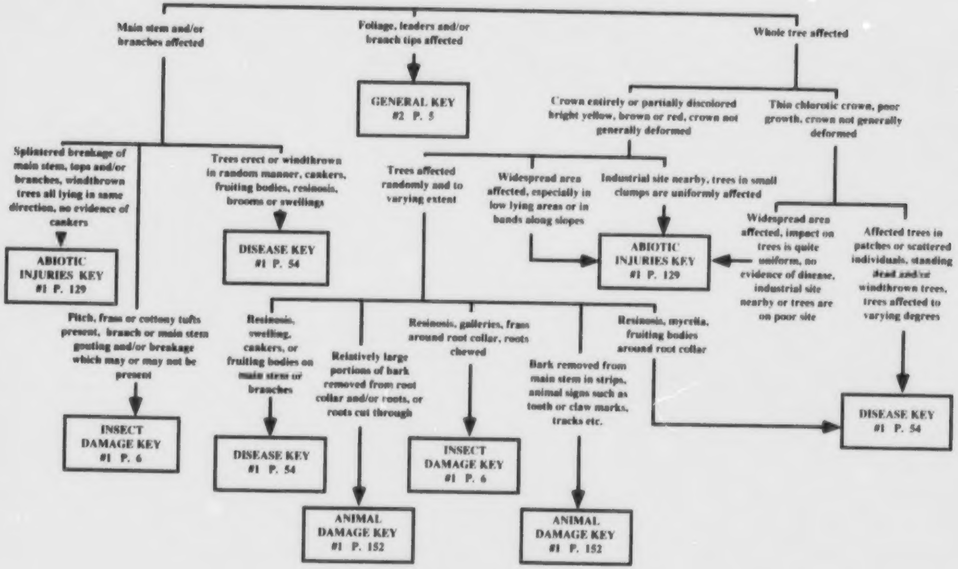
INTRODUCTION TO FOREST INSECT PESTS

Insects cause greater economic loss than any other pest group affecting British Columbia's managed forests. Insect outbreaks often occur sporadically and are characterized by rapid increases in population size and resultant damage levels. This has serious implications for effective control strategies. The selection of non-susceptible species, establishment of mixed stands, removal of slash and standing dead timber, and occasional use of pesticides or biological control agents constitute the most common insect pest management techniques. These methods may limit insect depredations but most harmful insect pests cannot be entirely eliminated, particularly over the course of a normal crop rotation. Therefore, the implementation of regular surveys to locate and monitor insect populations is of prime importance. Accurate pest identification and assessment form the foundation of such surveys.

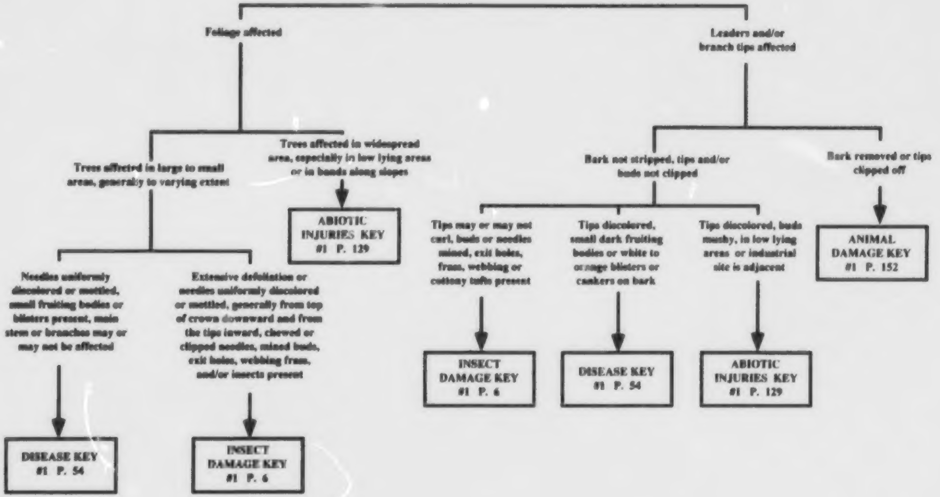
To facilitate identification, the insects discussed in this field guide are divided into the following categories: defoliators, sucking insects, and woody tissue feeders. Defoliators are perhaps the most common group, and are responsible for more province-wide damage to managed stands than the other two categories of insect pest. However, the importance of a particular species will often vary from one location to the next. Separation of these three groups is based on feeding habit. Defoliators feed on foliage and buds by means of cutting and chewing mouth parts. Woody tissue feeders have similar mouth parts but feed instead in the outer sapwood of the main stem, branches, root collar or roots, or the woody tissue within branch tips and leaders. Sucking insects have characteristic piercing and sucking mouth parts for removal of sap from needles, branches or stems. In any case, the larval stage of most species in these categories is responsible for the vast majority of damage and is generally the most conspicuous. Thus, larval description is usually emphasized in this guide.

Obviously, the presence of larvae is generally restricted to a small portion of the year. Therefore, the observer must frequently base a diagnosis on the resultant feeding damage. Sucking insects and woody tissue feeders often cause fairly distinctive injury. Gouting, deformity or chlorosis result from infestations by sucking insects. Woody tissue feeders create pitch nodules or tunnels in the wood, or destroy leaders and branch tips. Frequently, evidence of defoliators, such as frass, webbing, mined or clipped needles and the overall appearance of the crown, is similar between species. The preferred host(s), pest range and history of local epidemics should be considered when attempting to identify any insect pest, especially when insects are not present.

General Key #1 - For Insect, Disease, Animal or Abiotic Injuries

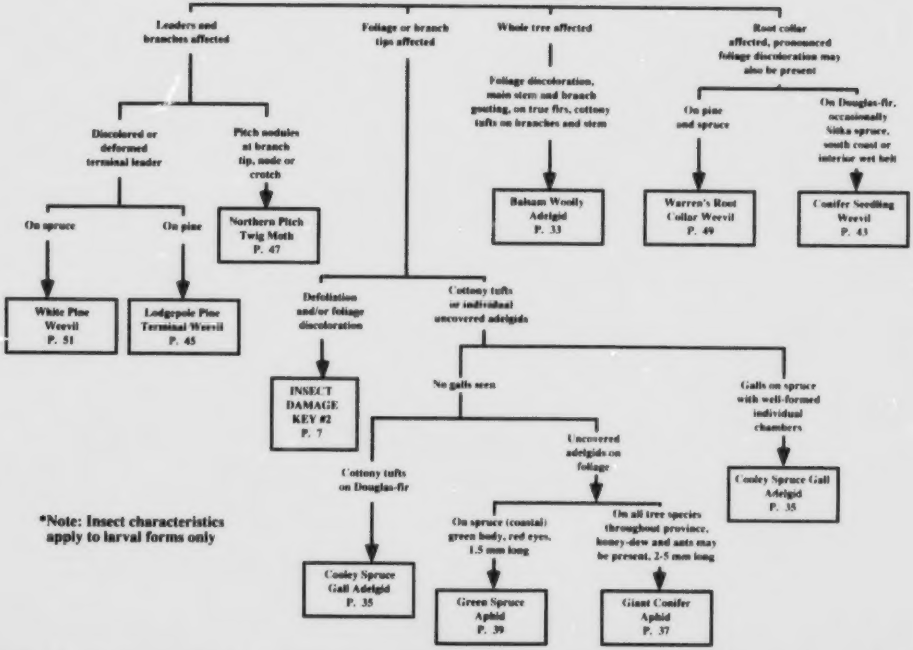

Main stem and/or branches affected
Foliage, leaders and/or branch tips affected
Whole tree affected
GENERAL KEY #2 P. 5
Splintered breakage of main stem, tops and/or branches, windthrown trees all lying in same direction, no evidence of cankers
ABIOTIC INJURIES KEY #1 P. 129
Trees erect or windthrown in random manner, cankers, fruiting bodies, resinosis, brooms or swellings
DISEASE KEY #1 P. 54
Pitch, frass or cottony tufts present, branch or main stem gouting and/or breakage which may or may not be present
INSECT DAMAGE KEY #1 P. 6
Crown entirely or partially discolored bright yellow, brown or red, crown not generally deformed
Thin chlorotic crown, poor growth, crown not generally deformed
Trees affected randomly and to varying extent
Widespread area affected, especially in low lying areas or in bands along slopes
Industrial site nearby, trees in small clumps are uniformly affected
ABIOTIC INJURIES KEY #1 P. 129
Widespread area affected, impact on trees is quite uniform, no evidence of disease, industrial site nearby or trees are on poor site
Affected trees in patches or scattered individuals, standing dead and/or windthrown trees, trees affected to varying degrees
Resinosis, swelling, cankers, or fruiting bodies on main stem or branches
DISEASE KEY #1 P. 54
Relatively large portions of bark removed from root collar and/or roots, or roots cut through
ANIMAL DAMAGE KEY #1 P. 152
Resinosis, galleries, frass around root collar, roots chewed
INSECT DAMAGE KEY #1 P. 6
Bark removed from main stem in strips, animal signs such as tooth or claw marks, tracks etc.
ANIMAL DAMAGE KEY #1 P. 152
Resinosis, mycelia, fruiting bodies around root collar
DISEASE KEY #1 P. 54

General Key #2 - For Insect, Disease, Animal or Abiotic Injuries



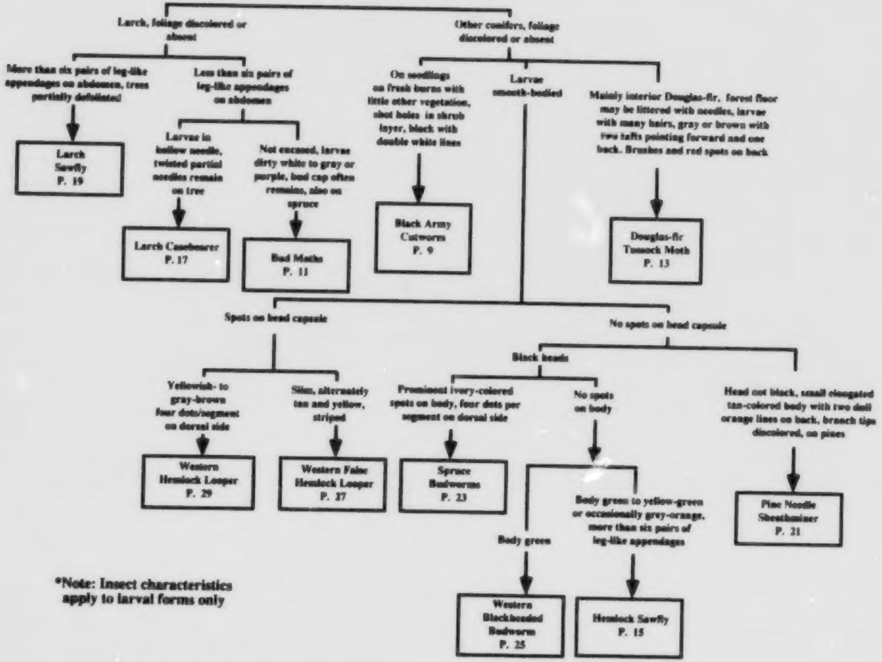
Foliage affected
Leaders and/or branch tips affected
Trees affected in large to small areas, generally to varying extent
Trees affected in widespread area, especially in low lying areas or in bands along slopes
ABIOTIC INJURIES KEY #1 P. 129
Needles uniformly discolored or mottled, small fruiting bodies or blisters present, main stem or branches may or may not be affected
DISEASE KEY #1 P. 54
Extensive defoliation or needles uniformly discolored or mottled, generally from top of crown downward and from the tips inward, chewed or clipped needles, mined buds, exit holes, webbing frass, and/or insects present
INSECT DAMAGE KEY #1 P. 6
Bark not stripped, tips and/or buds not clipped
Bark removed or tips clipped off
ANIMAL DAMAGE KEY #1 P. 152
Tips may or may not curl, buds or needles mined, exit holes, frass, webbing or cottony tufts present
INSECT DAMAGE KEY #1 P. 6
Tips discolored, small dark fruiting bodies or white to orange blisters or cankers on bark
DISEASE KEY #1 P. 54
Tips discolored, buds mushy, in low lying areas or industrial site is adjacent
ABIOTIC INJURIES KEY #1 P. 129

Insect Damage Key #1 - Woody Tissue Feeders and Sucking Insects *


Leaders and branches affected
Foliage or branch tips affected
Whole tree affected
Root collar affected, pronounced foliage discoloration may also be present
Discolored or deformed terminal leader
Pitch nodules at branch tip, node or crotch
On spruce
On pine
White Pine Weevil P. 51
Lodgepole Pine Terminal Weevil P. 45
Northern Pitch Twig Moth P. 47
Foliage discoloration, main stem and branch gouting, on true firs, cottony tufts on branches and stem
Balsam Woolly Adelgid P. 33
On pine and spruce
Warren's Root Collar Weevil P. 49
On Douglas-fir, occasionally Sitka spruce, south coast or interior wet belt
Conifer Seedling Weevil P. 43
Defoliation and/or foliage discoloration
INSECT DAMAGE KEY #2 P. 7
Cottony tufts or individual uncovered adelgids
No galls seen
Galls on spruce with well-formed individual chambers
Cooley Spruce Gall Adelgid P. 35
Cottony tufts on Douglas-fir
Cooley Spruce Gall Adelgid P. 35
Uncovered adelgids on foliage
On spruce (coastal) green body, red eyes, 1.5 mm long
Green Spruce Aphid P. 39
On all tree species throughout province, honey-dew and ants may be present, 2-5 mm long
Giant Conifer Aphid P. 37

*Note: Insect characteristics apply to larval forms only

Insect Damage Key #2 - Defoliators *


Larch, foliage discolored or absent
Other conifers, foliage discolored or absent
More than six pairs of leg-like appendages on abdomen, trees partially defoliated
Less than six pairs of leg-like appendages on abdomen
Larch Sawfly P. 19
Larvae in hollow needle, twisted partial needles remain on tree
Not encased, larvae dirty white to gray or purple, bud cap often remains, also on spruce
Larch Casebearer P. 17
Bud Moths P. 11
On seedlings on fresh burns with little other vegetation, shot holes in shrub layer, black with double white lines
Black Army Cutworm P. 9
Larvae smooth-bodied
Mainly interior Douglas-fir, forest floor may be littered with needles, larvae with many hairs, gray or brown with two tufts pointing forward and one back. Brushes and red spots on back
Douglas-fir Tussock Moth P. 13
Spots on head capsule
No spots on head capsule
Yellowish- to gray-brown four dots/segment on dorsal side
Slim, alternately tan and yellow, striped
Western Hemlock Looper P. 29
Western False Hemlock Looper P. 27
Black heads
Prominent ivory-colored spots on body, four dots per segment on dorsal side
No spots on body
Spruce Budworms P. 23
Body green
Body green to yellow-green or occasionally grey-orange, more than six pairs of leg-like appendages
Western Blackheaded Budworm P. 25
Hemlock Sawfly P. 15
Head not black, small elongated tan-colored body with two dull orange lines on back, branch tips discolored, on pines
Pine Needle Sheathminer P. 21

*Note: Insect characteristics apply to larval forms only

DEFOLIATORS

Defoliators are among the most destructive forest insect pests. Forests of any age class may be attacked. The larvae (caterpillars) of moths (Lepidoptera) and sawflies (Hymenoptera) are the most important defoliators of conifers. Defoliator feeding damage may include mining of needles and buds during the early stages of larval development followed by open feeding on the foliage. Needles may be entirely or only partially consumed. Defoliation primarily results in reduced growth and lost volume with little resultant mortality. Volume loss can be significant but is sometimes difficult to detect. Occasionally, severe defoliation occurs over several consecutive years, causing serious losses.

Damage symptoms indicating the presence of defoliator activity include: discoloration or loss of foliage, generally progressing from the top downward and from the branch tips inward; mined, chewed or clipped needles on the tree or accumulated on the ground; abundant webbing in the crown; accumulations of insect frass; and the presence of defoliating insects at various stages of development. Larval stages are responsible for the actual defoliation. Caterpillars, which may be smooth or hairy and have less than six pairs of leg-like appendages on the abdomen, are the larval stage of moths (Lepidoptera). They may vary in coloration or markings as they mature through several steps or instars. Sawfly larvae resemble caterpillars except they have six or more pairs of leg-like appendages on the abdomen.

Pupae are often found on the host or in the duff. They are generally oblong to cylindrical, papery or leathery and variable in color from white or grey to dark brown. Adult flights may occur any time from spring to fall, depending upon the species. Eggs are minute and, for some species, represent the overwintering stage. They can be found either singly or in clusters on the host or nearby vegetation. Damage forecasts for defoliators are based on egg or larval sampling, mass rearings and pheromone trapping. Climatic conditions and biological control factors make accurate population predictions difficult. Pesticides are occasionally used to reduce damage in severe outbreaks. Photographs and descriptions of important defoliators follow.

BLACK ARMY CUTWORM *Actebia fennica* (Tausch.)

DISTRIBUTION: Damaging populations have occurred in the central and southeastern Interior.

TREE SPECIES ATTACKED: All conifer seedlings, most commonly white spruce and lodgepole pine.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are velvety black on the upper surface with two pairs of fine white double lines running the full length of each side of the body. The underside is gray. The larvae range from about 0.5 cm long during the overwintering stage, to about 4.0 cm when mature in June. Larvae feed during the day in early spring but switch to night feeding in late spring.

Although larvae prefer to feed on herbaceous plants and shrubs, such as fireweed, they will defoliate coniferous seedlings in the absence of preferred hosts. Attacked coniferous seedlings may be partially or completely defoliated and buds may be damaged.

DAMAGE: Adult moths are attracted to recently burned areas to lay their eggs. Sites burned in early summer the previous year, or in late summer to fall two years previous, are the most attractive. If preferred vegetation is scarce when larvae emerge in the spring, the potential for damage to planted coniferous stock is very high, especially if the cutworm population is high. Severe defoliation may result in seedling mortality or deformity. Although attacks can be devastating locally, this insect seldom causes significant damage for more than one season.

REFERENCES: Ross, D.A.; Ilnytzky, S. 1977. The black army cutworm in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-154. 23p.

Ross, D.A.; Monts, J.S. 1976. Black army cutworm, pest of conifer seedlings. Canadian Forestry Service, Pacific Forest Research Centre. Fact Sheet.

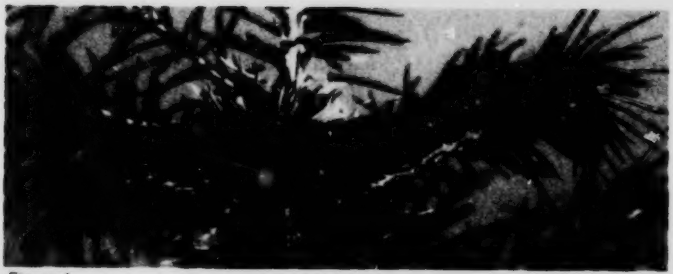


Figure 1.
BLACK ARMY CUTWORM larva. Note fine double lines along the abdomen.

Figure 2.
Conifer seedling defoliated by BLACK ARMY CUTWORM due to absence of preferred herbaceous hosts.

Figure 3.
BLACK ARMY CUTWORM feeding on herbaceous vegetation.

Figure 4.
Current growth of spruce seedling after severe defoliation by BLACK ARMY CUTWORM the previous year.

BUD MOTHS *Zeiraphera* spp.

DISTRIBUTION: Throughout the province following the range of spruce and larch.

TREE SPECIES ATTACKED: Spruce, larch and occasionally true firs.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are up to 1.4 cm long when fully grown. Larval body color is variable and may be any of the following: pale green, dirty white, pale yellow or yellowish green to purplish brown. Light brown spots may be present on the back or side of the larvae. The heads are broad and black when young but eventually turn brown.

Bud moth larvae feed only on current year's foliage. On spruce, the larvae attack recently flushed buds. Many larvae secure the bud cap to the bud with silk strands and feed on the new foliage under the shelter of the bud cap. This type of feeding is not conspicuous at first, but later in the season most attacked buds will retain their caps while healthy buds will not. Larvae may create feeding shelters by chewing needles off at the base and attaching them to twigs. On larch, young larvae feed on developing needle clusters. Older larvae construct tube-like structures from needle clusters and webbed tunnels along the branch axis, or they may feed directly on needles.

DAMAGE: Since budmoths feed on current growth only, damage is limited to growth reduction and distortion of crowns. In some cases, however, this damage is extensive, causing reduction in stand performance, especially in young plantations.

REFERENCES: Carrow, J.R. 1985. Spruce budmoth - a case history: opportunities. Forestry Chronicle 61: 247-251.

Werner, R.A. 1980. Biology and behavior of a larch bud moth, *Zeiraphera* spp., in Alaska. U.S.D.A. Forest Service. Research Note PNW-356. 8p.

Figure 5.
Frass on bud indicates BUD MOTH feeding. Note retention of bud cap.

Figure 6.
BUD MOTH larvae on larch needle clusters. Note very small size. Body color varies.

Figure 7.
BUD MOTH attack on true fir showing resultant leader damage.

Figure 8.
BUD MOTH feeding damage to larch needle cluster.

DOUGLAS-FIR TUSSOCK MOTH *Orgyia pseudotsugata* (McD.)

DISTRIBUTION: Warm, dry areas of the southern Interior and occasionally on the South Coast.

TREE SPECIES ATTACKED: Principally Douglas-fir but other species such as ponderosa pine and western larch are occasionally attacked if adjacent to infested Douglas-fir.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Young larvae emerge in late May to early June. They are 0.3 cm in length, light to dark brown, and covered with fine hairs. Mature larvae reach 3.0 cm in length and have four yellow to tan, rust-tipped tussocks on their backs and red spots located on the upper surface of each of the next three segments. There is one dark-colored pencil-like tuft behind each side of the head and one on the posterior. The head is glossy black. The entire body is covered with hairs growing from small red nodes. A broken orange-yellow stripe runs along each side of the body.

Young larvae prefer current foliage but mature larvae will consume older foliage. Silk threads will be evident, especially in tree tops. The upper third of the crown is defoliated first. Defoliation is most evident in late July when attacked trees initially turn reddish brown then grayish purple.

DAMAGE: Douglas-fir tussock moth has the potential to cause significant mortality due to defoliation. In addition, top-kill, growth reduction and secondary attacks by insects and fungi may follow severe defoliation.

REFERENCES: Brookes, M.H.; Stark, R.W.; Campbell, R.W.; eds. 1978. The Douglas-fir tussock moth: a synthesis. U.S.D.A. Forest Service. Technical Bulletin 1585. 331p.

Erickson, R.D. 1978. The Douglas-fir tussock moth. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 9. 3p.

Wickman, B.E.; Mason, R.R.; Trostle, G.C. 1981. Douglas-fir tussock moth. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 86. 10p.

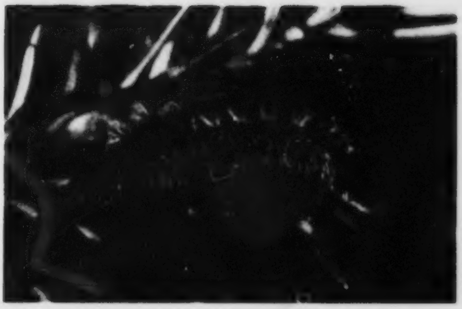


Figure 9.
Distinctive mature larva of DOUGLAS-FIR TUSSOCK MOTH.

Figure 10.
Silk webbing in tree top produced by DOUGLAS-FIR TUSSOCK MOTH infestation.

Figure 11.
DOUGLAS-FIR TUSSOCK MOTH egg mass with young larvae emerging.

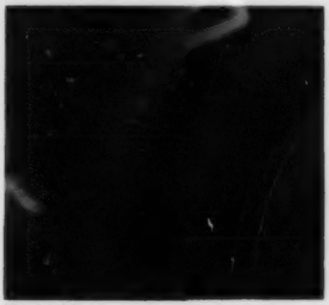


Figure 12.
DOUGLAS-FIR TUSSOCK MOTH often defoliates upper third of crown first.

HEMLOCK SAWFLY *Neodiprion tsugae* Midd.

DISTRIBUTION: Coastal and interior wet belt areas of British Columbia.

TREE SPECIES ATTACKED: Western hemlock and amabilis fir are most frequently attacked, but Sitka spruce may also be damaged.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are present from June to August. Newly emerged larvae are almost black, with a shiny black head. Mature larvae are 1.5 - 2.0 cm long and are green or yellow-green, with a broad medium-dark band on each side and a narrower, darker band below that. The head remains dark.

Larvae are wasteful feeders of older foliage; current foliage may be eaten under starvation conditions. Larvae often feed in colonies, especially when young. When disturbed, larvae will hold on with hind legs and flick the front of the body. Cocoons are formed during July and early August and are commonly found in the lower crown under twigs or needles or on understory vegetation. They are 0.5 - 1.0 cm long, cylindrical, have rounded ends, vary from light gray to brown in color, and are tough and papery.

DAMAGE: Hemlock sawfly usually affects older foliage only. Therefore, mortality is not common but some top-kill and radial growth loss may occur. The potential for mortality is greatly increased by repeated defoliation or when hemlock sawfly occurs with defoliators which prefer current foliage, such as western blackheaded budworm. Hemlock sawfly damage may predispose trees to secondary attacks by other insects or fungi. Outbreaks are usually short-lived.

REFERENCES: Hard, J.S.; Torgersen, T.R.; Schmiege, D.C. 1976. Hemlock sawfly. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 31. 7p.

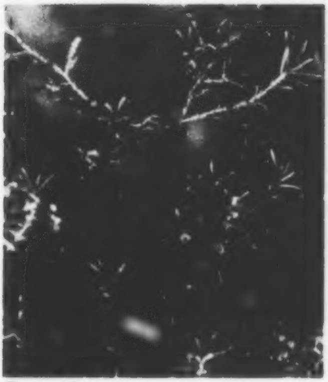


Figure 13.
Older foliage is preferred by HEMLOCK SAWFLY.

Figure 14.
Mortality of western hemlock caused by HEMLOCK SAWFLY.

Figure 15.
HEMLOCK SAWFLY larva.

LARCH CASEBEARER *Coleophora laricella* (Hbn.)

DISTRIBUTION: Southeastern British Columbia from the Okanagan Valley east to the Crowsnest Pass and north to Vernon. Defoliation is more common at lower elevations.

TREE SPECIES ATTACKED: Western larch.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Mature larvae are 0.5 cm long and are dark reddish brown with a black head. Young larvae mine a single needle and fabricate a hollow shelter, called a 'case', from a section of the needle. This 'case' is straw-colored and rectangular, becoming gray and cigar-shaped prior to pupation. Larvae move about and feed on needles while enclosed in the case. By late summer the larvae fasten the case to twigs or a needle fascicle to overwinter. Foliage damage is most visible in May when late-instar larvae are feeding on new foliage.

The new foliage of lightly attacked larch turns light green to straw-colored and will curl at the end. A severe attack will produce reddish needles which create a scorched appearance. Defoliation is usually lightest in the lower crown and increases with height. Late-instar larvae feeding in the spring are responsible for the majority of damage. In severe attacks foliage may be consumed as fast as it is produced. Trees often flush again in June if defoliated in May.

DAMAGE: Larch are relatively resistant to the effects of defoliation. However, after five years of severe defoliation, annual terminal and radial growth may be seriously affected.

REFERENCES: Dawson, A.F. 1973. Larch casebearer in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 34. 5p.

Ross, D.A. 1976. Larch casebearer foliage feeder. Canadian Forestry Service, Pacific Forest Research Centre. Pamphlet.

Tunnock, S.; Ryan, R.B. 1985. Larch casebearer in western larch. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 96. 8p.

Figure 16.
Straw colored foliage of larch attacked by LARCH CASEBEARER.

Figure 17.
Rectangular case of immature LARCH CASEBEARER larva.

Figure 18.
Mined needles and cigar–shaped case of mature LARCH CASEBEARER larvae.

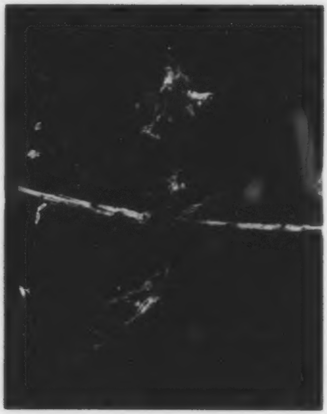


Figure 19.
Defoliation of new foliage by LARCH CASEBEARER.

LARCH SAWFLY *Pristiphora erichsonii* (Htg.)

DISTRIBUTION: On western larch in the east Kootenays and throughout the range of eastern larch (tamarack) in northern British Columbia.

TREE SPECIES ATTACKED: Western larch and eastern larch.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Young larvae have cream-colored bodies and brown heads. As they mature, their bodies become greenish and eventually gray-green on top and whitish underneath. The heads darken to become shiny black. Full-grown larvae reach 2.0 cm in length, and may be seen holding on with their forelegs and arching their back with their posterior end over the head.

Eggs are laid in slits in terminal shoots and twigs in June or July. Larvae emerge from the slits shortly thereafter and feed in groups, stripping the foliage as they move down the branch. Terminal shoots and twigs are damaged during egg-laying and may be left curled and distorted for several years.

DAMAGE: Larch are very tolerant of defoliation; therefore, no reports of direct tree mortality on western or eastern larch have resulted from larch sawfly attack in British Columbia. Growth reduction and branch mortality may, however, occur following outbreaks. Outbreaks may cover thousands of hectares.

REFERENCES: Drooz, A.T. 1971. Larch sawfly. U.S.D.A. Forest Service. Forest Pest Leaflet 8. 5p.

Erickson, R.D. 1984. Larch sawfly. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 12. 4p.

Figure 20.
Maturing LARCH SAWFLY larvae. Gregarious feeding is common.

Figure 21.
Tip curl is an early symptom of LARCH SAWFLY attack.

Figure 22.
Severely defoliated larch due to LARCH SAWFLY infestation.

PINE NEEDLE SHEATHMINER *Zelleria haimbachi* Bsk.

DISTRIBUTION: Throughout southern British Columbia.

TREE SPECIES ATTACKED: Lodgepole pine, ponderosa pine and occasionally white pine. Found mostly in juvenile stands.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Immature larvae are about 0.2 cm long and reach 1.4 cm prior to pupation. Larvae are tan-colored with two dull orange stripes running lengthwise along the body. The color changes to a greenish hue before pupation.

On damaged trees, the current year's foliage appears faded and needles may be shorter than normal. Some needles may droop back, or hook, towards the needle base. A small hole may be noted in the sheath surrounding an attacked fascicle. By late summer, damaged needles are shed and commonly accumulate in webs along the main stem. Feeding occurs throughout the growing season.

DAMAGE: Attacks usually occur in juvenile to immature pine stands. Damage is restricted to the current year's foliage, but up to 100% of the new growth may be destroyed over hundreds of hectares. The extent of defoliation varies among trees within an attacked stand, and some trees may escape attack entirely. Tree mortality has not been associated with this insect. However, growth reduction resulting from defoliation has been documented in ponderosa pine plantations.

REFERENCES: Stevens, R.E. 1971. Pine needle sheathminer. U.S.D.A. Forest Service. Forest Pest Leaflet 65. 5p.

Stevens, R.E. 1971. Pine growth retarded following defoliation by the pine needle sheathminer. Journal of Economic Entomology 64: 1572-1573.

Figure 23.
PINE NEEDLE SHEATHMINER larvae are relatively small and tan colored.

Figure 24. Fading of current year's foliage due to attack by PINE NEEDLE SHEATHMINER.

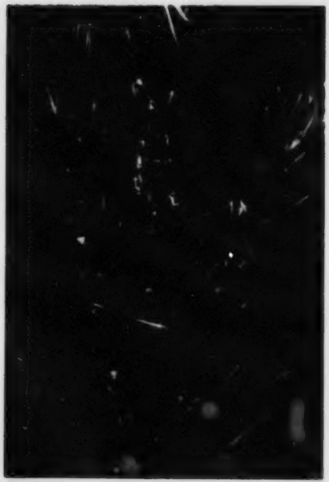


Figure 25.
Frass, webbing and necrotic needles resulting from attack by PINE NEEDLE SHEATHMINER.

SPRUCE BUDWORMS *Choristoneura* spp.

Note: Several species belonging to this genus are similar in appearance and cause similar damage. They will therefore be considered together.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: Douglas-fir, true firs and spruce are the primary hosts. Larch, western hemlock and pine species are attacked occasionally.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Young larvae are 0.2-0.4 cm in length and yellow-green. As they age, larvae become orange-brown at 0.5-0.7 cm in length and olive-brown at 0.6-1.2 cm. Full-grown larvae are 2.5-3.0 cm long with reddish to olive-brown bodies and sometimes have a green tinge on the upper surface. Each body segment has four distinct light-colored spots. The head color varies from light brown to black.

Young larvae mine needles and buds from late April to early June and feed on current foliage after bud flush. Older larvae prefer current foliage but will feed on older foliage if current foliage is depleted. The crowns of damaged trees appear reddish brown from June to August. The initial symptoms of defoliation may be seen in tree tops and branch tips, where loose needles accumulate in webbing.

DAMAGE: Tree mortality may occur after several successive years of severe defoliation, particularly on immature or suppressed trees. Trees which survive are often left with dead tops. Height and radial growth may be severely reduced for one to two years following severe attacks.

REFERENCES: Fellin, D.G.; Dewey, J.E. 1982. Western spruce budworm. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 53. 9p.

Ross, D.A. 1977. Western spruce budworm on Douglas-fir. Canadian Forestry Service, Pacific Forest Research Centre. Pamphlet.

Unger, L.S. 1983. Spruce budworms in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 31. 4p.

Figure 26.
Maturing SPRUCE BUDWORM larva. Note color and four spots on each abdominal segment.

Figure 27.
Initial defoliation caused by SPRUCE BUDWORM.

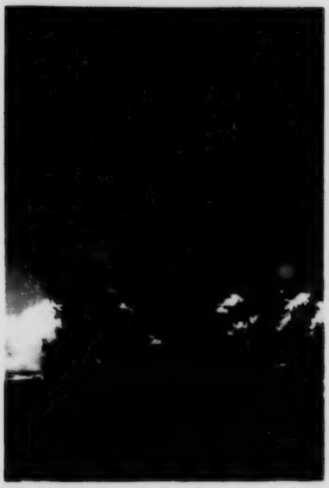


Figure 28.
SPRUCE BUDWORM infestations often result in high mortality.

Figure 29.
Dead top as a result of successive defoliation by SPRUCE BUDWORM.

WESTERN BLACKHEADED BUDWORM *Acleris gloverana* (Wlshm.)

DISTRIBUTION: Throughout British Columbia except the Ponderosa Pine Biogeoclimatic Zone.

TREE SPECIES ATTACKED: Western hemlock, amabilis fir and Sitka spruce are the principal hosts on the Coast. Western hemlock, Engelmann spruce, white spruce, subalpine fir and Douglas-fir are attacked in the Interior. The species also occurs on other conifers during epidemics.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: When young, larvae are pale yellow-green with a brown to black head. With age, the body becomes green and the head brown. The larvae reach a length of approximately 1.5 cm in the last instar.

Visible defoliation occurs from late June to late July in the Interior and from mid-July to mid-August on the Coast. Needles of opening buds are usually only partially eaten and some are clipped off at the base and webbed together on the twigs. From a distance the damaged stand has a reddish brown hue. Current foliage is preferred, but older needles will be attacked during heavy infestations. Pupation takes place within webs spun in the twig foliage.

DAMAGE: The western blackheaded budworm prefers to feed on the upper crowns of dominant and codominant trees. Trees can be completely defoliated from a heavy attack. This severe defoliation may result in growth reduction and predisposition to attacks from secondary organisms. Successive years of severe defoliation may result in tree mortality. Second-growth hemlock stands that have been severely defoliated for two successive years have sustained greater than 10% mortality; 75% of the remaining trees have suffered an average of 8 m of top-kill.

REFERENCES: Koot, H.P. 1978. Western blackheaded budworm. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 24. 4p.

Schmiege, D.C.; Crosby, D. 1970. Black-headed budworm in western United States. U.S.D.A. Forest Service. Forest Pest Leaflet 45. 4p.

Figure 30.
Mature WESTERN BLACKHEADED BUDWORM larva and webbing.

Figure 31.
WESTERN BLACKHEADED BUDWORM initially feeds on current foliage.

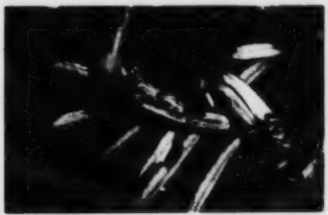


Figure 32.
WESTERN BLACKHEADED BUDWORM only partially consumes needles.

Figure 33.
Hemlock stand defoliated by WESTERN BLACKHEADED BUDWORM.

Figure 34.
WESTERN BLACKHEADED BUDWORM often defoliates the upper crown first.

WESTERN FALSE HEMLOCK LOOPER *Nepytia freemani* Mun.

DISTRIBUTION: Primarily occurs in the Interior Douglas-fir Biogeoclimatic Zone, most often occurring in Douglas-fir stands growing on dry, rocky sites.

TREE SPECIES ATTACKED: Immature Douglas-fir and occasionally western hemlock, Engelmann spruce, subalpine fir, ponderosa pine and larch.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae appear with the flush of new growth in the spring. Mature larvae have a broad reddish brown dorsal stripe bordered by narrow yellow stripes. Each side is marked with a wide yellow stripe. The length is approximately 3 cm. The head appears almost square from above and has black dots.

Feeding begins in the upper crown on newly flushed foliage. Later, the larvae move down the crown and consume older foliage. Most needles are only partially eaten. Larvae are solitary feeders but may gather in webbed enclosures to pupate. Defoliation becomes noticeable in June. Abundant webbing is evident in heavily infested stands.

DAMAGE: During serious outbreaks, trees may be completely defoliated in one season. Douglas-fir usually recovers from a single defoliation. Repeated attacks, however, can result in top-kill or mortality.

REFERENCES: Ferris, R.L.; Woensdregt, H.A. 1983. Western false hemlock looper in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 59. 4p.

Harris, J.W.E.; Dawson, A.F.; Brown, R.G. 1985. The western false hemlock looper in British Columbia 1942-1984. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-269. 11p.

Figure 35.
Late instar larva of WESTERN FALSE HEMLOCK LOOPER. Note square head and alternating dark and light stripes.

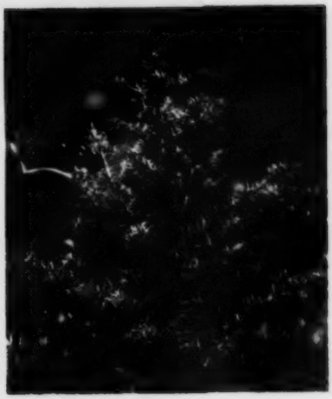


Figure 36.
Feeding by WESTERN FALSE HEMLOCK LOOPER begins in new foliage of tree tops.

Figure 37.
WESTERN FALSE HEMLOCK LOOPER larvae gradually consume older foliage further down the crown.

WESTERN HEMLOCK LOOPER *Lambdina fiscellaria lugubrosa* (Hulst)

DISTRIBUTION: This species primarily occurs south of 56° latitude and is most common along the coast and in the interior wet belt of British Columbia. Outbreaks have occurred on stands from sea level to 400 m elevation.

TREE SPECIES ATTACKED: Western hemlock is the preferred host, but western red cedar, Douglas-fir, Sitka spruce and other conifers are also susceptible to attack.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are typical loopers and are approximately 3.5 cm in length when mature. Young larvae are marked with light gray and black bands. Mature larvae are yellowish brown to light gray with an intricate pattern of darker markings. Each abdominal segment is marked with four prominent dark spots which roughly form a square.

Larvae emerge in late spring and begin feeding in newly opened buds in the upper crown. Later, the larvae feed on foliage of any age and disperse throughout the crown. Larvae are wasteful feeders. Many needles are only partially chewed; some are severed at the base and accumulate below an attacked tree. Mature larvae are quite mobile and produce an abundance of silk webbing which is very evident in defoliated stands. The crowns of heavily attacked trees turn yellowish red at first and eventually reddish brown. Defoliation occurs most commonly on sites located in valley bottoms with a major western hemlock component.

DAMAGE: Western hemlock is intolerant of defoliation; thus, mortality can occur following only one year of heavy defoliation and may continue for up to four years after the collapse of a western hemlock looper infestation. Most hemlock can recover from less than 50% defoliation.

The wasteful feeding habit of this insect greatly increases the amount of damage relative to most other defoliators. Older hemlock, amabilis fir and Sitka spruce are most vulnerable to damage while young Douglas-fir appears to suffer more than older. Outbreaks generally last for three years. Serious damage has occurred in hemlock-true fir mixes on the coast and hemlock-cedar stands in the interior wet belt of the province.

REFERENCES: Erickson, R.D. 1984. Western hemlock looper. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 21. 4p.

Harris, J.W.E.; Dawson, A.F.; Brown, R.G. 1982. The western hemlock looper in British Columbia 1911-1980. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-234. 15p.

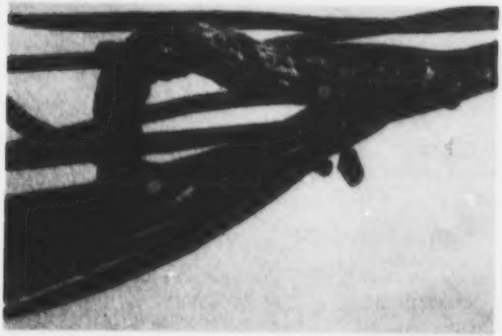


Figure 38.
Mature larva of WESTERN HEMLOCK LOOPER on larch. Note intricate pattern of markings.

Figure 39.
WESTERN HEMLOCK LOOPER usually begins feeding on current growth in late spring.

Figure 40.
Detail showing wasteful feeding habit of WESTERN HEMLOCK LOOPER

SUCKING INSECTS

Sucking insects, primarily aphids, affect either foliage or the branches and main stem. Foliage attacks are characterized by chlorotic mottling or needle drop due to removal of the sap during feeding. Stem or branch attacks can result in galls on the branch tips, swellings and deformities on the branches and main stem, or growth reduction. These galls, swellings, and deformities result from injection of digestive juices into the host when the sucking insects feed. Nymphs, immature insects that resemble the adults, and winged or wingless adults are often present in large congregations on the foliage, stem or branches. Depending on the species, adults and nymphs may be covered with a white and waxy deposit which gives them a cottony appearance. Other species are smooth, oval and greenish to black. Sucking insects may be mobile or permanently positioned on a particular feeding spot. Life cycles of most species are complex and require alternate hosts for completion.

Douglas-fir, true fir and spruce species are the most frequent hosts, but attacks are generally sporadic. Balsam woolly adelgid causes the most significant damage, followed by the cooley spruce gall adelgid. Damage varies according to host; however, growth reduction and occasional mortality can result. Epidemics are usually of short duration. The sporadic nature of outbreaks and the very high reproduction rate of these insects make control efforts difficult. Photographs and descriptions of the most important sucking insects follow.

BALSAM WOOLLY ADELGID *Adelges piceae* (Ratz.)

DISTRIBUTION: The mainland coast north to Powell River, Vancouver Island north to Parksville and West Thurlow Island. This pest is subject to quarantine regulations.

TREE SPECIES ATTACKED: All true firs, with amabilis and grand firs attacked most frequently. Grand fir is most tolerant of attack; subalpine fir is most easily damaged.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Adults are tiny (less than 0.1 cm) insects covered with wool-like wax threads. Masses of feeding adults, appearing as thousands (up to 100 per square centimeter) of tiny (0.2 cm in diameter) tufts of wool, may be visible on the smooth bark of younger trees and in the bark crevices of older trees. Rubbing the wool tufts during summer months should produce a purple stain on the fingers.

Crown-attacked trees have thin, chlorotic to red-brown upper crowns, stunted terminal growth and possibly a dead top. Closer examination of the top will reveal swellings around buds and branch nodes (termed "gouting"). Decay fungi may be associated with these symptoms.

Stem-attacked trees exhibit a general decline, with the entire crown being chlorotic to red-brown and possibly thin. Stem attack, however, is less common than and always associated with crown attack. This insect is difficult to see during the winter months. Therefore, diagnosis during winter should be based on gouting and crown symptoms.

DAMAGE: Attacks occur most commonly on large trees, but all age classes of trees are susceptible. The intensity of attack will vary within an infested stand. Outbreaks have been associated with sites disturbed by logging, road building or drought. Crown attack produces dead tops and growth reduction, but most trees can survive crown attack for several years. Stem attack has a more severe effect on the host tree, which may die following 2-3 years of repeated infestations.

REFERENCES: Carrow, J.R. 1974. Detection of balsam woolly aphid. Canadian Forestry Service, Pacific Forest Research Centre. Forest Insect and Disease Survey Fact Sheet. 2p.

Harris, J.W.E. 1978. Balsam woolly aphid. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 1. 4p.

Mitchell, R.G.; Amman, G.D.; Waters, W.E. 1970. Balsam woolly aphid. U.S.D.A. Forest Service. Forest Pest Leaflet 118. 10p.

Figure 41.
Wool-like tufts cover feeding BALSAM WOOLLY ADELGIDS.

Figure 42.
Distorted crown resulting from BALSAM WOOLLY ADELGID attack.

Figure 43.
Gouting due to infestation by BALSAM WOOLLY ADELGID.

Figure 44.
Stunted terminal growth from continual BALSAM WOOLLY ADELGID crown infestation.

Figure 45.
BALSAM WOOLLY ADELGID adults without tufts.

COOLEY SPRUCE GALL ADELGID *Adelges cooleyi* (Gill.)

DISTRIBUTION: Throughout the province wherever Douglas-fir is established.

TREE SPECIES ATTACKED: Alternates between Douglas-fir and Sitka, Engelmann or white spruce.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS:

On Douglas-fir - Adults are about 0.1 cm long, oval, and light to dark brown in color. At maturity they are completely covered with white, waxy wool and appear, from spring to fall, as stationary wool tufts on the underside of needles. The needles of light to moderately infested trees exhibit chlorotic mottling where individual adults have fed. Attacked needles may also be twisted. Severely infested foliage may be completely chlorotic and drop prematurely.

On spruce - The adult is similar to that found on Douglas-fir. Infested spruce display cone-like galls at the ends of branches. These galls are 1-8 cm long with separate chambers. New galls are green, pink or purple and flexible; the chambers are closed and may contain aphids. As they age, galls become brown, hard and brittle; the chambers are open and empty. Old galls may persist on spruce branches for several years.

DAMAGE:

On Douglas-fir - Light infestations are very common, though not seriously damaging. Significant damage, however, including needle loss and growth reduction, occurs sporadically when young trees are severely attacked.

On spruce - Repeated attacks can produce stunted, deformed trees, but normally cooley spruce gall adelgid is not a concern in spruce stands.

REFERENCES: Campbell, R.L.; Balderston, C.P. 1972. Insecticidal control of *Adelges cooleyi* on Douglas-fir in Ohio, with notes on biology. Journal of Economic Entomology 65: 912-914.

Wood, C. 1977. Cooley spruce gall aphid. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 6. 4p.

Figure 46.
Non-tufted and tufted COOLEY SPRUCE GALL ADELGIDS on Douglas-fir foliage. Note wool-like appearance of tufts.

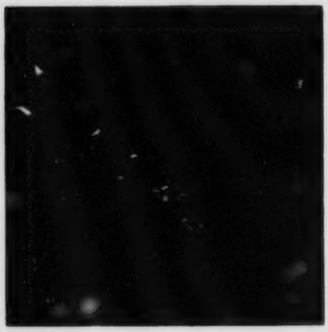


Figure 47.
Infestation by COOLEY SPRUCE GALL ADELGID is characterized by white tufts from spring to fall.

Figure 48.
Cross-section of gall showing oval chambers which contain developing COOLEY SPRUCE GALL ADELGIDS.

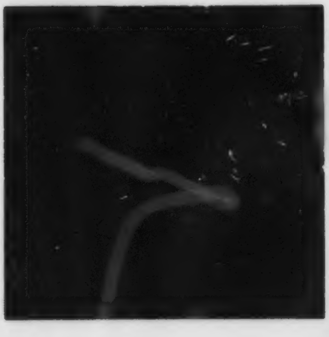


Figure 49.
New gall (above) caused by COOLEY SPRUCE GALL ADELGID. Old gall (below) is necrotic and brown.

GIANT CONIFER APHID *Cinara* spp.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: All native conifers.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Adult giant conifer aphids are pear-shaped, 0.2-0.5 cm in length and usually dark-colored. Adults have long, slender legs and may have wings. Nymphs are similar in shape and color to adults but lack wings and are slightly smaller. The aphids feed in a stationary group and may be found on branches, roots or the main stem. A clear sticky liquid, called honeydew, is exuded from the posterior of each aphid. Ants frequently harvest honeydew from the aphids. A black, sooty mold often develops on foliage and branches covered by honeydew. Foliage of infested trees may become chlorotic.

DAMAGE: Attack can cause growth reduction in young conifers. Studies have shown that the leaders of infested trees may be only one-quarter to one-half the length of similar non-infested trees. Aphid attack may predispose a tree to secondary insects, pathogenic fungi or excessive drought stress.

REFERENCES: Johnson, N.E. 1965. Reduced growth associated with infestations of Douglas-fir seedlings by *Cinara* species. Canadian Entomologist 97: 113-119.

Figure 50.
GIANT CONIFER APHID nymphs and adults (magnified).

Figure 51.
Chlorosis due to feeding by GIANT CONIFER APHID.

Figure 52.
GIANT CONIFER APHID is a gregarious feeder. This large congregation is on spruce.

GREEN SPRUCE APHID *Elatobium abietinum* (Wlk.)

DISTRIBUTION: Throughout coastal British Columbia wherever Sitka spruce occurs.

TREE SPECIES ATTACKED: Sitka spruce is preferred; other spruce species may be attacked.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Nymphs or adult aphids are found on the lower surface of needles where they suck the sap. Nymphs are wingless, oval and green, and approximately 0.1 cm long. Adults may be winged or wingless, and are 0.2 cm long but are otherwise similar in body shape and color to nymphs. Adults have a yellow-green head and dull red eyes. Eggs are oval-shaped and are yellowish red to brown or black. Foliage discoloration and defoliation are most noticeable in early spring. Individual needles exhibit chlorotic mottling. Infested crowns turn a dull green to brownish color.

DAMAGE: The nymphs' feeding habits cause foliage discoloration and subsequent needle drop. Severe and extensive damage is occasionally reported on the Queen Charlotte Islands, particularly on trees growing along the shoreline. In other areas, infestations tend to be sporadic in nature and rarely affect more than several hundred trees. Trees are usually only partially defoliated and recover with some loss in growth rate. Complete defoliation and mortality occur occasionally.

REFERENCES: Holms, J.C.; Ruth, D.S. 1968. Spruce aphid in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 16. 5p.

Figure 53.
GREEN SPRUCE APHIDS feeding on the underside of needles.

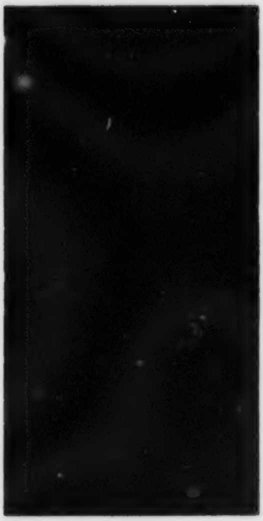


Figure 54.
Crown discoloration resulting from GREEN SPRUCE APHID infestation.

Figure 55.
Chlorotic mottling due to attack by GREEN SPRUCE APHID.

Figure 56.
Severe needle drop after attack by GREEN SPRUCE APHID.

WOODY TISSUE FEEDERS

This group of insects causes significant damage in immature pine and spruce species. Most woody tissue feeders are bark beetles, which cause very high losses in mature and overmature stands throughout British Columbia. Outstanding examples are mountain pine beetle and spruce beetle. However, these particular insects rarely attack younger stands. Juvenile trees, from seedlings to pole-sized individuals, are more prone to attack by other types of woody tissue feeders, including weevil species and the northern pitch twig moth. These insects feed primarily on the innermost bark (phloem) of the roots, root collar, leaders, branch tips or branch junctions.

The larval stage is usually responsible for most of the damage, with the exception of the conifer seedling weevil. Larvae are pale, legless and grub-like (weevil larvae) or cream to orange-brown in color (northern pitch twig moth larvae) and create characteristic girdling patterns, pitch nodules, or dead or broken leaders and tips. Larvae of Warren's root collar weevil and the northern pitch twig moth usually feed individually, while larvae of other species may feed in groups. Adults are weevils with typical snouts or, in the case of the northern pitch twig moth, small moths.

Leader and branch crotch attacks may cause reduced growth, breakage, deformity and dieback. Weevil-killed terminals can be distinguished from those killed by other agents by the presence of round adult exit holes or larvae feeding inside the terminals. Infestations are usually scattered throughout a plantation and are relatively slow to spread. Effective control measures do not yet exist. Photographs and descriptions of important woody tissue feeders follow.

CONIFER SEEDLING WE[illegible]. *Steremnius carinatus* (Boh.)

DISTRIBUTION: The coastal and interior wetbelt areas of British Columbia.

TREE SPECIES ATTACKED: Seedlings of Douglas-fir and Sitka spruce are preferred. Hemlock, true fir and western red cedar seedlings are also attacked.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Adults are about 1 cm long, rough textured and brick-red in color when young, becoming brown to yellowish as they age. Adult weevils are most abundant in spring and fall. They feed on a wide variety of plants, including young coniferous seedlings. Damaged seedlings are partially or completely girdled. Injuries usually occur near the root collar but can extend several centimeters up the stem. Girdled seedlings turn yellow or red. Damage can appear randomly throughout an infested area. Attacks are most common on cool, damp sites with an abundance of organic material.

DAMAGE: This weevil normally feeds on herbaceous species. Girdling of conifer seedlings is usually a problem only on sites where natural ground cover is removed by fire or site preparation prior to planting conifers. Partially girdled seedlings may recover; seedling mortality usually occurs only when seedlings are completely girdled. Damage is most extensive in first year plantations and is negligible after one growing season.

Populations of weevils build up for several years in debris left during logging and right-of-way clearing. Thus, attacks usually occur on prepared sites established adjacent to 1-3 year old openings. Conifer seedling weevil may act as a vector of black stain root disease in Douglas-fir.

REFERENCES: Condrashoff, S.F. 1968. Biology of *Steremnius carinatus* (Coleoptera: Curculionidae), a reforestation pest in coastal British Columbia. Canadian Entomologist 100: 386-394.

Condrashoff, S.F. 1969. *Steremnius carinatus* (Boheman), a weevil damaging coniferous seedlings in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-17. 6p.

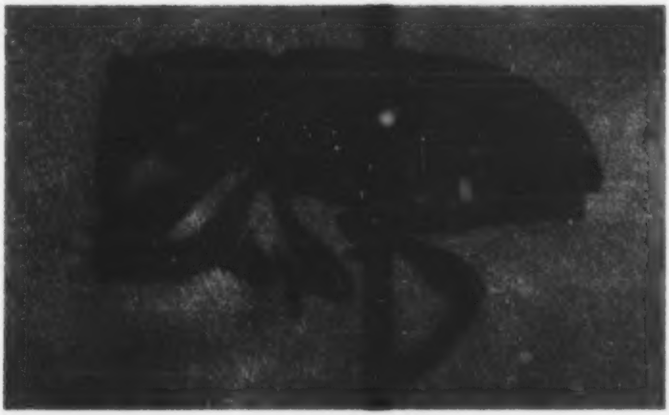


Figure 57.
CONIFER SEEDLING WEEVIL adult.
Note rough texture and color.

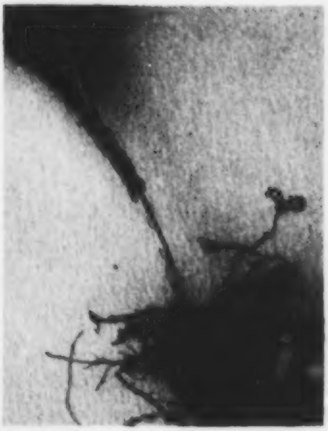


Figure 58.
Seedling completely girdled by
CONIFER SEEDLING WEEVIL.

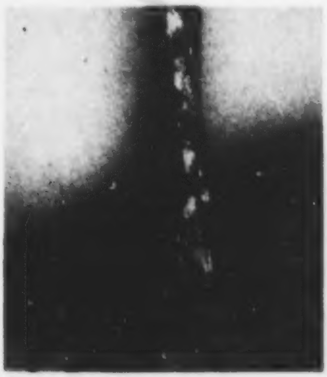


Figure 59.
Sections of bark removed from stem by
CONIFER SEEDLING WEEVIL.

LODGEPOLE PINE TERMINAL WEEVIL *Pissodes terminalis* Hopping

DISTRIBUTION: Throughout the range of lodgepole pine, south of 50° latitude.

TREE SPECIES ATTACKED: Lodgepole pine, usually from 1.5 to 10 m in height.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are stout, curved, legless grubs. The body is yellowish white and the heads are brown. The length may reach 1.2 cm in the final instar. Adults are mottled reddish brown weevils with a long curved snout. Their length varies from about 0.4 to 1.0 cm.

The first sign of attack appears in late spring to early summer when small punctures appear at the base of the current year's leader. Resin droplets are associated with these wounds. By mid-summer, the current year's leader is chlorotic. The color gradually changes from yellow to red to brown. In late summer to fall, large holes made by emerging adults may be noted midway down the dead current year's leader. Signs of attack from previous years include deformed or multiple leaders and dead stubs along main stems.

DAMAGE: This weevil prefers the most vigorous, open grown trees and causes terminal dieback of the current year's growth. In addition to growth loss, attacks reduce timber quality by inducing forked and crooked stems. The best time to evaluate damage is August to September. Repeated attacks occurring over several years can result in deformed, multi-leadered trees.

REFERENCES: Duncan, R.W. 1986. Terminal and root-collar weevils of lodgepole pine in British Columbia. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 73. 6p.

Ives, W.G.J. 1983. Insect and disease pests and allied problems affecting lodgepole pine in Alberta: regeneration and management. U.S.D.A. Forest Service. General Technical Report PNW-157. 52p.

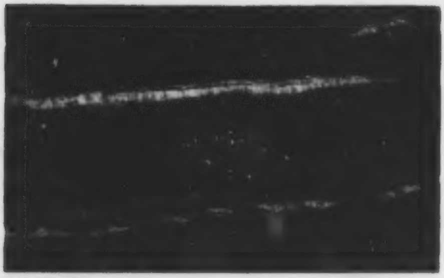


Figure 60.
Yellowish white larva of LODGEPOLE PINE TERMINAL WEEVIL mining leader of lodgepole pine.

Figure 61.
LODGEPOLE PINE TERMINAL WEEVIL pupa within mined terminal.

Figure 62.
Killed and discolored lodgepole pine leader due to attack by LODGEPOLE PINE TERMINAL WEEVIL. Only current year's growth is destroyed.

Figure 63.
Lodgepole pine foliage fading due to attack by LODGEPOLE PINE TERMINAL WEEVIL.

NORTHERN PITCH TWIG MOTH *Petrova albicapitana* (Bsk.)

DISTRIBUTION: Interior regions of the province following the range of the host species.

TREE SPECIES ATTACKED: Lodgepole pine.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: The larvae are about 1.5 cm long. The color of the body varies from yellow to orange-brown. The head is reddish brown. Characteristic pitch nodules occur near terminal buds, the crotch of branch junctions, or at the crotch of the main stem and branches. These nodules consist of pitch and frass and conceal a single feeding larva in a silk-lined inner chamber. The nodules produced at branch or stem crotches are usually 2.0 cm or more in diameter and are formed by older larvae. Those occurring at terminal buds are usually less than 1.0 cm in diameter and are produced by newly emerged larvae.

DAMAGE: Feeding larvae can kill the tips of branches or terminal shoots by girdling the inner bark. Occasionally the nodules on the main stem become large enough to kill the top of a tree. More typically, however, the damaged area is weakened and therefore subject to wind or snow breakage. In addition, larval feeding may reduce timber quality by inducing crooked leaders. Plantations are more heavily attacked than densely stocked, naturally regenerated stands. This insect rarely attacks suppressed trees.

REFERENCES: Duncan, R.W. 1982. Common pitch moths of pine in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 69. 7p.

Turnock, W.J. 1953. Some aspects of the life history and ecology of the pitch nodule maker, *Petrova albicapitana* (Busck) (Lepidoptera-Olethreutidae). Canadian Entomologist 85: 233-243.

Wong, H.R.; Drouin, J.A.; Rentz, C.L. 1985. *Petrova albicapitana* (Busck) and *P. metallica* (Busck) (Lepidoptera: Tortricidae) in *Pinus contorta* Dougl. stands of Alberta. Canadian Entomologist 117: 1463-1469.

Figure 64.
NORTHERN PITCH TWIG MOTH larvae feed singly within a nodule.

Figure 65.
Girdling by NORTHERN PITCH TWIG MOTH larva.

Figure 66.
NORTHERN PITCH TWIG MOTH feeding often occurs near branch junctions. Trees are subsequently deformed and weakened.

Figure 67.
Breakage and deformity caused by NORTHERN PITCH TWIG MOTH attack.

WARREN'S ROOT COLLAR WEEVIL *Hylobius warreni* Wood

DISTRIBUTION: Throughout the interior of the province, following the range of its hosts. Optimal conditions for this weevil occur on moist sites with coarse-textured soils and a heavy duff layer.

TREE SPECIES ATTACKED: Lodgepole pine, Engelmann spruce and white spruce. Usually, only trees over 2 cm in diameter at the root collar are attacked.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are large (up to 2 cm in the final instar), legless, and creamy white. The heads are orange-brown. The flightless adults are typical weevils with a prominent curved snout. They are from 1.0 to 1.5 cm long and thick-bodied with dull black-flecked coloring and gray-white scales.

Infested plantations display random mortality of single or small groups of trees. Damaged trees exhibit straw-colored to deep red foliage and stunted terminal growth. Damaged trees are usually easy to push over or have an obvious lean. Positive identification requires careful examination of the tree root collar. During feeding, larvae tunnel into the phloem, cambium and slightly into the wood of the root collar area. Tunneling damage is always associated with large quantities of resin mixed with the soil surrounding the damaged roots.

DAMAGE: Larvae are responsible for the majority of the damage. Young trees may be completely girdled at the root collar and die. Older trees are often partially girdled at the root collar, and may be completely girdled around some of the roots; however, no mortality results. Significant damage often occurs when a young stand is located adjacent to an older infested stand. In addition to direct mortality, damaged trees may suffer growth loss and increased susceptibility to root rot and blue stain fungi. No preweakening of host trees is required for attack, and studies indicate that weevil populations increase as duff depth increases.

REFERENCES: Cerezke, H.F. 1970. A method for estimating abundance of the weevil, *Hylobius warreni* Wood, and its damage in lodgepole pine stands. Forestry Chronicle 46: 392-396.

Duncan, R.W. 1986. Terminal and root-collar weevils of lodgepole pine in British Columbia. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 73. 6p.

Wilson, L.F.; Millers, I. 1983. Pine root collar weevil - its ecology and management. U.S.D.A. Forest Service. Technical Bulletin 1675. 34 p.

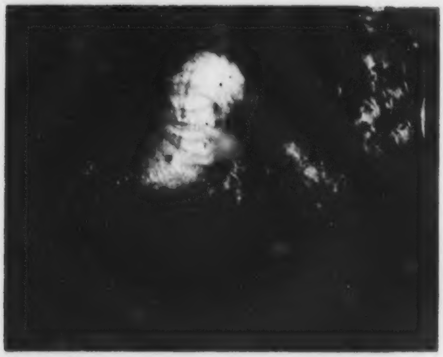


Figure 68.
Larvae of WARREN'S ROOT COLLAR WEEVIL are large and creamy white.

Figure 69.
Crown symptoms due to girdling by WARREN'S ROOT COLLAR WEEVIL.

Figure 70.
Typical damage to root collar and roots from WARREN'S ROOT COLLAR WEEVIL.

Figure 71.
WARREN'S ROOT COLLAR WEEVIL adult.

WHITE PINE WEEVIL *Pissodes strobi* (Pk.)
Previously called Sitka spruce or Englemann spruce weevil.

DISTRIBUTION: Throughout the range of spruce, south of 56°latitude, except the Queen Charlotte Islands.

TREE SPECIES ATTACKED: Sitka, white and Engelmann spruce. Trees from 1.5 - 10 m in height are preferred.

INSECT DESCRIPTION AND DAMAGE SYMPTOMS: Larvae are stout, curved, legless grubs. The body is yellowish-white and the heads are brown. Larvae may reach 1.2 cm in length by the final instar. Adults are reddish brown to black with cream markings. Their long curved snout is typical of weevils. Length varies from about 0.4 to 1.0 cm, and the abdomens are heavily scaled and mottled in appearance.

The first sign of attack appears in spring, when small punctures appear near the tip of the previous year's leader. Resin droplets are associated with these wounds. By mid-summer, the current year's leader on attacked trees will be distorted and wilted. This shepherd's crook gradually changes from yellow to red to brown and is indicative of weevil attack. In late summer to fall, large holes made by emerging adults will be noted midway down the previous year's leader. At this time the current and previous year's leader are usually dead. Signs of previous attacks include deformed or multiple leaders and dead stubs along main stems.

DAMAGE: This weevil prefers vigorous, open grown trees and causes terminal dieback of at least two years' growth. In addition to growing loss, attacks may reduce timber quality by inducing forked and crooked stems. Repeated attacks may allow less desirable species to become dominant over the host species. The best time to evaluate damage is from August to September.

REFERENCES: McMullen, L.H. 1976. Spruce weevil damage, ecological basis and hazard rating for Vancouver Island. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-141. 2p.

Wood, R.O.; McMullen, L.H. 1983. Spruce weevil in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet

Figure 72.
WHITE PINE WEEVIL larva feeding within spruce leader.

Figure 74.
Spruce with dead top resulting from earlier attack by WHITE PINE WEEVIL. Both previous and current year's growth are killed.

Figure 76.
Frass plugs along leader indicate internal feeding by WHITE PINE WEEVIL.

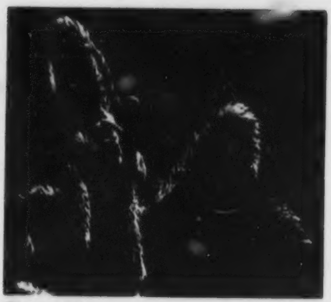


Figure 73.
Shepherd's crook is an early indication of WHITE PINE WEEVIL attack.

Figure 75.
Exit hole made by emerging WHITE PINE WEEVIL adult.

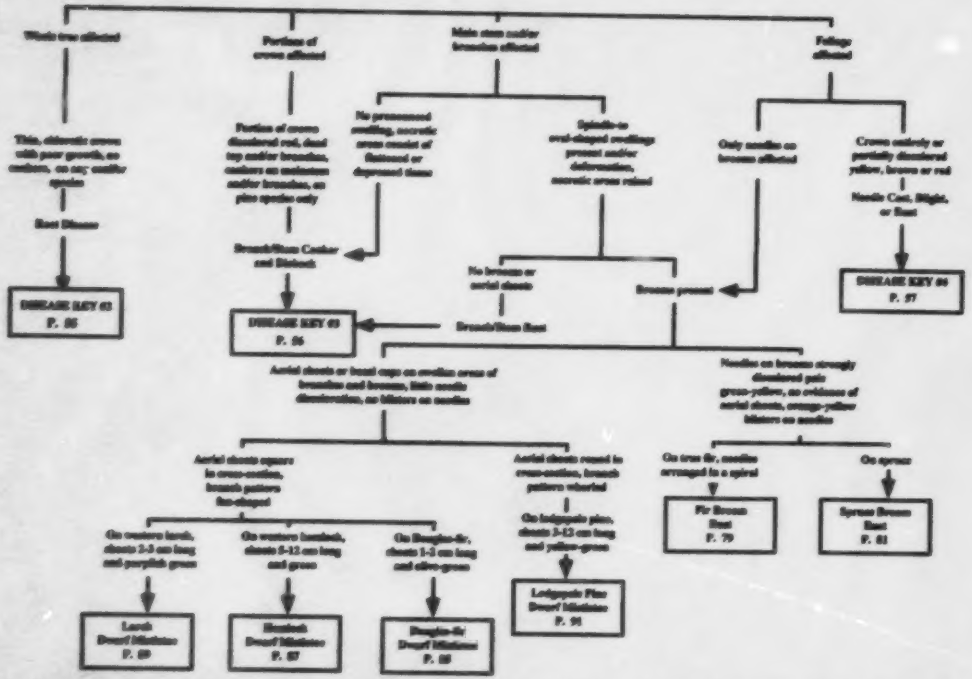
INTRODUCTION TO FOREST DISEASES

Forest diseases are responsible for significant timber losses in British Columbia, and are second only to insect pests in impact. Root disease fungi and dwarf mistletoes account for the greatest proportion of these losses. However, the relative importance of a particular disease organism often varies from one region to the next. For example, direct losses to Armillaria root disease are greater in the interior of British Columbia than on the coast. Conversely, hemlock dwarf mistletoe is a serious coastal pathogen but is not found in interior hemlock stands. Detailed information on disease distribution can be obtained from Information Report BC-X-281 (Distribution Maps of Common Tree Diseases in British Columbia.), issued by Forestry Canada, Pacific Forestry Centre, Victoria.

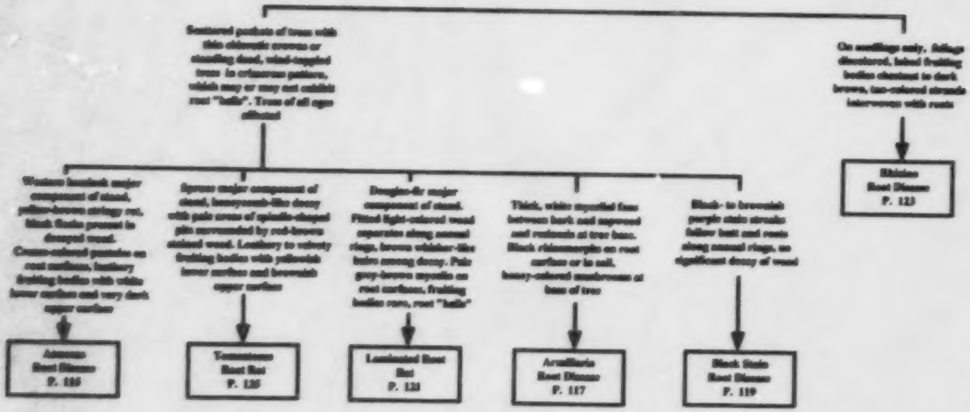
Losses in actual and potential wood volume and in wood quality occur in a relatively slow and non-cyclical manner, unlike most damage resulting from insect infestations. When forest managers implement silvicultural programs, losses due to disease or other agents are considered to be inevitable and tolerable within certain defined limits. However, forest management practices have a significant long term effect on whether or not a serious disease problem will occur over a normal rotation. Poor procedures, such as the reestablishment of susceptible species on root rot infected sites or failure to remove all dwarf mistletoe-infected trees at time of harvest, may favor the occurrence of unacceptable damage levels in the future. Thus, early implementation of strategies which limit losses is of paramount importance. These strategies include selection of non-susceptible species, selection programs for resistant cultivars, branch pruning, spacing operations, stump and root extraction, site preparation, and harvest scheduling.

Of course, early and accurate disease identification and assessment through routine field surveys provide the foundation upon which timely and cost effective decisions can be made. Diagnosis will be facilitated if the following points are considered. Diseases result when certain fungal or parasitic plant species gain entry to one or more areas of a host and form particular host-pathogen relationships during which the pathogen obtains nutrients and the host is injured. Needle or tip necrosis, wood rotting and/or staining, deformity, and stem/branch cankering subsequently occur, depending on the specific host-pathogen interaction. However, generalized symptoms are often manifested on areas of the host that do not actually support the pathogen. More specific symptoms are found at the point(s) of infection, together with fruiting bodies, depending on time of year or stage of infection. Fruiting bodies vary widely in size, shape and color from minute, powdery or pimple-like structures (casts, rusts, blights, cankers and diebacks) to relatively large characteristic mushrooms and conks (root diseases). Accordingly, this section is divided into the following disease groups: branch/stem cankers and diebacks; branch/stem rusts; broom rusts; dwarf mistletoes; needle casts; blights and rusts; and root diseases.

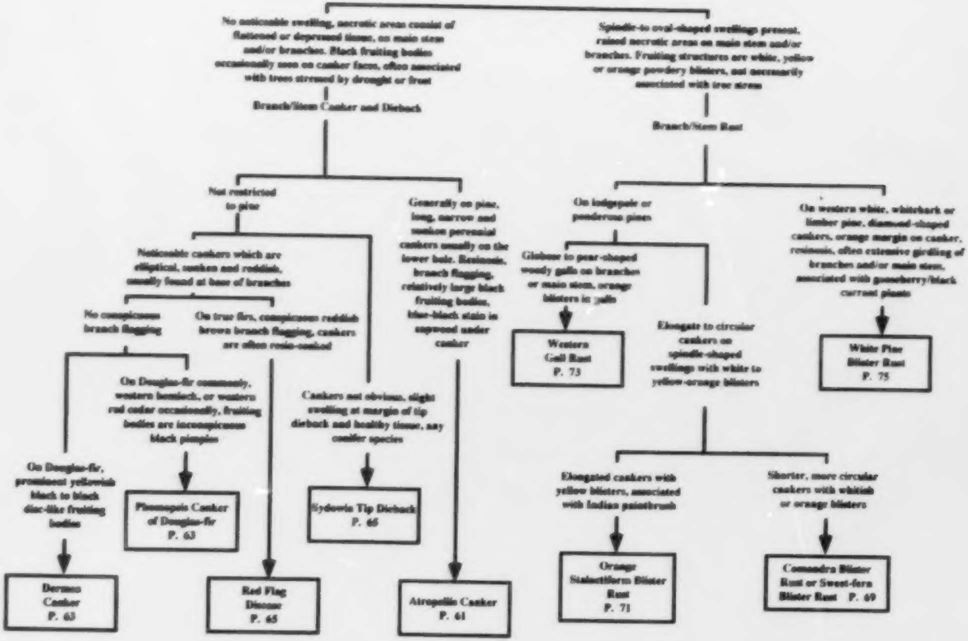
Disease Key #1 - Dwarf Mistletoes and Broom Rusts


Whole tree affected
Thin, chlorotic crown with poor growth, no cankers, on any conifer species
Root Disease
DISEASE KEY #2 P. 55
Portion of crown affected
Portion of crown discolored red, dead top and/or branches, cankers on main stem and/or branches, on pine species only
Branch/Stem Canker and Dieback
DISEASE KEY #3 P. 56
Main stem and/or branches affected
No pronounced swelling, necrotic areas consist of flattened or depressed tissue
Spindle-to oval-shaped swellings present and/or deformation, necrotic areas raised
No brooms or aerial shoots
Branch/Stem Rust
Brooms present
Foliage affected
Only needles on brooms affected
Crown entirely or partially discolored yellow, brown or red
Needle Cast, Blight, or Rust
DISEASE KEY #4 P. 57
Aerial shoots or basal cups on swollen areas of branches and brooms, little needle discoloration, no blisters on needles
Needles on brooms strongly discolored pale green-yellow, no evidence of aerial shoots, orange-yellow blisters on needles
Aerial shoots square in cross-section, branch pattern fan-shaped
Aerial shoots round in cross-section, branch pattern whorled
On lodgepole pine, shoots 3-12 cm long and yellow-green
Lodgepole Pine Dwarf Mistletoe P. 91
On western larch, shoots 2-3 cm long and purplish green
Larch Dwarf Mistletoe P. 89
On western hemlock, shoots 5-12 cm long and green
Hemlock Dwarf Mistletoe P. 87
On Douglas-fir, shoots 1-2 cm long and olive-green
Douglas-fir Dwarf Mistletoe P. 85
On true fir, needles arranged in a spiral
Fir Broom Rust P. 79
On spruce
Spruce Broom Rust P. 81
]

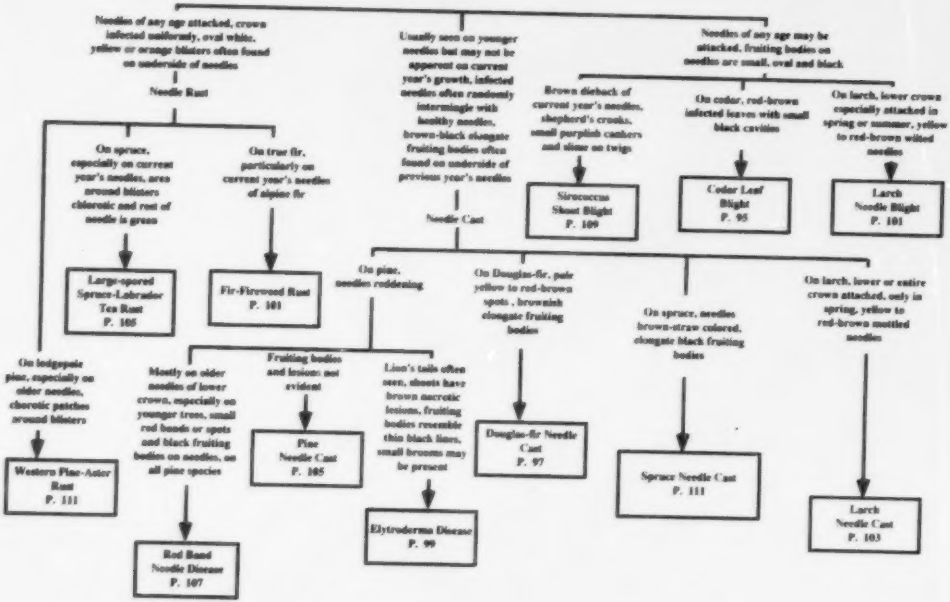
Disease Key #2 - Root Diseases


Scattered pockets of trees with thin chlorotic crowns or standing dead, wind-tipped trees in crisscross pattern, which may or may not exhibit root "balls". Trees of all ages affected
On seedlings only, foliage discolored, lobed fruiting bodies chestnut to dark brown, tan-colored strands interwoven with roots
Rhizina Root Disease P. 123
Western hemlock major component of stand, yellow-brown stringy rot, black flecks present in decayed wood. Cream-colored pustules on root surfaces, leathery fruiting bodies with white lower surface and very dark upper surface
Annosus Root Disease P. 115
Spruce major component of stand, honeycomb-like decay with pale areas of spindle-shaped pits surrounded by red-brown stained wood. Leathery to velvety fruiting bodies with yellowish lower surface and brownish upper surface
Tomentosus Root Rot P. 125
Douglas-fir major component of stand. Pitted light-colored wood separates along annual rings, brown whisker-like hairs among decay. Pale grey-brown mycelia on root surfaces, fruiting bodies rare, root "balls"
Laminated Root Rot P. 121
Thick, white mycelial fans between bark and sapwood and resinosis at tree base. Black rhizomorphs on root surface or in soil. honey-colored mushrooms at base of tree
Armillaria Root Disease P. 117
Black- to brownish purple stain streaks follow bark and roots along annual rings, no significant decay of wood
Black Stain Root Disease P. 119

Disease Key #3 - Branch/Stem Cankers and Diebacks, and Branch/Stem Rust Diseases


No noticeable swelling, necrotic areas consist of flattened or depressed tissue, on main stem and/or branches. Black fruiting bodies occasionally seen on canker faces, often associated with trees stressed by drought or frost
Branch/Stem Canker and Dieback
Spindle-to oval-shaped swellings present, raised necrotic areas on main stem and/or branches. Fruiting structures are white, yellow or orange powdery blisters, not necessarily associated with tree stress
Branch/Stem Rust
Not restricted to pine
Generally on pine, long, narrow and sunken perennial cankers usually on the lower bole. Resinosis, branch flagging, relatively large black fruiting bodies, blue-black stain in sapwood under canker
On lodgepole or ponderosa pines
On western white, whitebark or limber pine, diamond-shaped cankers, orange margin on canker, resinosis, often extensive girdling of branches and/or main stem, associated with gooseberry/black currant plants
Noticeable cankers which are elliptical, sunken and reddish, usually found at base of branches
Globose to pear-shaped woody galls on branches or main stem, orange blisters in galls
No conspicuous branch flagging
On true firs, conspicuous reddish brown branch flagging, cankers are often resin-soaked
Western Gall Rust P. 73
Elongate to circular cankers on spindle-shaped swellings with white to yellow-orange blisters
White Pine Blister Rust P. 75
On Douglas-fir commonly, western hemlock, or western red cedar occasionally, fruiting bodies are inconspicuous black pimples
Cankers not obvious, slight swelling at margin of tip dieback and healthy tissue, any conifer species
On Douglas-fir, prominent yellowish black to black disc-like fruiting bodies
Elongated cankers with yellow blisters, associated with Indian paintbrush
Shorter, more circular cankers with whitish or orange blisters
Phomopsis Canker of Douglas-fir P. 63
Sydowia Tip Dieback P. 66
Dermea Canker P. 63
Red Flag Disease P. 65
Atropellis Canker P. 61
Orange Stalactiform Blister Rust P. 71
Comandra Blister Rust or Sweet-fern Blister Rust P. 69

Disease Key #4 - Needle Casts, Blights and Rusts


Needles of any age attacked, crown infected uniformly, oval white, yellow or orange blisters often found on underside of needles
Needle Rust
On spruce, especially on current year's needles, area around blisters chlorotic and rest of needle is green
Large-spored Spruce-Labrador Tea Rust P. 105
On true fir, particularly on current year's needles of alpine fir
Fir-Fireweed Rust P. 101
On lodgepole pine, especially on older needles, chorotic patches around blisters
Western Pine-Aster Rust P. 111
Usually seen on younger needles but may not be apparent on current year's growth, infected needles often randomly intermingle with healthy needles, brown-black elongate fruiting bodies often found on underside of previous year's needles
Needle Cast
On pine, needles reddening
Mostly on older needles of lower crown, especially on younger trees, small red bands or spots and black fruiting bodies on needles, on all pine species
Red Band Needle Disease P. 107
Fruiting bodies and lesions not evident
Pine Needle Cast P. 105
Lion's tails often seen, shoots have brown necrotic lesions, fruiting bodies resemble thin black lines, small brooms may be present
Elytroderma Disease P. 99
On Douglas-fir, pale yellow to red-brown spots , brownish elongate fruiting bodies
Douglas-fir Needle Cast P. 97
On spruce, needles brown-straw colored, elongate black fruiting bodies
Spruce Needle Cast P. 111
On larch, lower or entire crown attached, only in spring, yellow to red-brown mottled needles
Larch Needle Cast P. 103
Needles of any age may be attacked, fruiting bodies on needles are small, oval and black
Brown dieback of current year's needles, shepherd's crooks, small purplish cankers and slime on twigs
Sirococcus Shoot Blight P. 109
On cedar, red-brown infected leaves with small black cavities
Cedar Leaf Blight P. 95
On larch, lower crown especially attacked in spring or summer, yellow to red-brown wilted needles
Larch Needle Blight P. 101

BRANCH/STEM CANKERS AND DIEBACKS

Branch/stem cankers and diebacks are bark diseases caused by fungi. Both healthy and stressed trees can be attacked; however, some diseases, such as Dermea canker, Phomopsis canker and Sydowia tip dieback, are almost exclusively associated with conditions of drought or frost stress in younger trees. All native conifers are susceptible to one or more species of fungi causing branch/stem cankers and diebacks. The most obvious symptom is the presence of cankers on the stem or branches, formed after invasion of the host bark by a fungal pathogen.

Cankers vary somewhat in appearance, depending upon the fungi and hosts involved. Generally, cankers are elongate to oval and sunken in the centre. Bark over the canker becomes discoloured, necrotic and sloughs off, leaving exposed sapwood which may or may not be stained. Small, black disc-like or pimply fruiting bodies are often seen on the canker face. In addition, resinosis is common around cankered areas. Cankers are either annual or perennial, according to species. Cankers which only form annually are generally less damaging. Annual cankers are smaller and flatter than perennial cankers which progress in size from one year to the next. Atropellis canker, an example of the latter type, causes mortality and growth reduction, particularly in dense pine stands. Annual cankers typically cause only branch or leader dieback and subsequent growth loss with extensive infections; mortality is usually restricted to severely stressed trees. Practical management options consist of avoidance of susceptible species during stock selection, removal of infected trees, maintenace of vigorous stands and development of resistant cultivars. Photographs and descriptions of the more common branch/stem cankers and diebacks follow.

ATROPELLIS CANKER *Atropellis piniphila* (Weir) Lohman and Cash

DISTRIBUTION: Southern and central British Columbia, following the range of lodgepole pine.

TREE SPECIES ATTACKED: Lodgepole pine, and occasionally ponderosa pine.

SIGNS AND SYMPTOMS: Branch flagging is often apparent in spring and early summer. Long, narrow perennial cankers are formed on the stem of the lower bole, usually around the axils of branches or twigs. Cankers are several times as long as they are wide. The cankered area is sunken with cracked, furrowed bark. A blue-black stain in the sapwood is present and a reddish color at the margin between the canker and healthy tissue may be noted. The stained sapwood is an important diagnostic feature because sapwood is not stained from stem rust cankers. However, staining from this disease must not be confused with wood discoloration caused by blue stain fungi. Copious resin flow occurs at the margin of Atropellis cankers. Relatively large (0.5-4.5 mm) black, cup-shaped fruiting bodies are occasionally present on bark covering the canker. If young vigorous trees are cut horizontally through the canker, the blue-black staining is roughly wedge-shaped with the point of the wedge towards the pith.

DAMAGE: Mortality, growth reduction and reduced commercial value can result from this disease. Suppressed trees can be killed by a single stem canker. Two or more cankers occurring at the same level can kill even a large vigorous tree. The commercial value of trees surviving canker attack is lowered because of staining and excess resin. Canker incidence is typically greatest in overstocked single-species stands such as fire-origin lodgepole pine. Infection levels have been reported to reach 100% in some cases.

REFERENCES: Hopkins, J.C. 1985. Atropellis canker. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 25. 4p.

Lightle, P.C.; Thompson, J. H. 1973. Atropellis canker of pines. U.S.D.A. Forest Service. Forest Pest Leaflet 138. 6p.

Figure 77. Developing ATROPELLIS CANKER on lodgepole pine. Note elongated shape and resin flow at canker margin.

Figure 78 Blue-black stain in wood underneath ATROPELLIS CANKER

Figure 79. Large sunken ATROPELLIS CANKER. Main stem is significantly weakened.

Figure 80. Stem breakage resulting from ATROPELLIS CANKER infection.

DERMEA CANKER *Dermea pseudotsugae* Funk

DISTRIBUTION: Throughout the province following the host range.

TREE SPECIES ATTACKED: Douglas-fir.

SIGNS AND SYMPTOMS: Dead tops and branches result from canker girdling. Needles on affected areas turn red and are shed a few months later. Infections on the stem mainly occur at branch bases and appear as patches of necrotic bark which are reddish and sunken. The bark covering the cankers eventually dries, cracks and is sloughed off. Secondary infections may result in cankered areas. Small black fruiting structures may be present on the surface of cankers.

DAMAGE: This disease has the potential to cause widespread mortality in young Douglas-fir stands. However, it is usually associated with adverse weather conditions such as early frost.

REFERENCES: Funk, A. 1967. *Dermea pseudotsugae* n. sp., a causal agent of phloem necrosis in Douglas-fir. Canadian Journal of Botany 45: 1803-1809.

PHOMOPSIS CANKER OF DOUGLAS-FIR *Phomopsis lokoyae* Hahn

DISTRIBUTION: The lower mainland and Vancouver Island.

TREE SPECIES ATTACKED: Douglas-fir and occasionally western hemlock and western red cedar.

SIGNS AND SYMPTOMS: Stem and branch cankers, which may cause dead branches and top dieback, result from infection. Cankers are elliptical and sunken and commonly have a dead twig or branch near the centre. Small (0.5 mm) black fruiting bodies cover the canker surface in spring and early summer. Tree foliage above girdled stems or branches turns red.

DAMAGE: Outbreaks are usually limited to single or small groups of trees. Cankers survive only one year although small trees are often girdled, with resultant mortality. Affected areas heal over on surviving trees. Larger trees usually survive infections although branches or tops may be killed. Infections usually follow stress caused by drought or frost.

REFERENCES: Funk, A. 1968. *Diaporthe lokoyae* n. sp., the perfect state of *Phomopsis lokoyae*. Canadian Journal of Botany 46: 601-603.

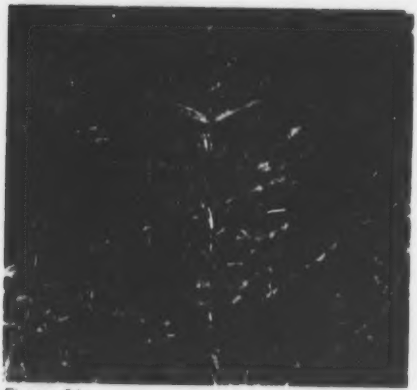


Figure 81.
Douglas-fir killed due to girdling by DERMEA CANKER.

Figure 82.
DERMEA CANKER showing reddish discoloration of bark.

Figure 83.
Mortality due to complete stem girdling by PHOMOPSIS CANKER OF DOUGLAS-FIR.

Figure 84.
Elliptical shape and sunken tissue typical of PHOMOPSIS CANKER OF DOUGLAS-FIR. Note dead twig in centre of canker.

RED FLAG DISEASE *Potebniamyces balsamicola* Smerlis

DISTRIBUTION: Throughout the province

TREE SPECIES ATTACKED: True firs

SIGNS AND SYMPTOMS: Red flag disease causes reddish brown branch flagging, dead branches, and leader dieback due to formation of annual cankers. On the stem, cankers are elliptical, sunken reddish brown patches on the bark. Mature cankers are usually resin-soaked, and small black fruiting structures are visible on the bark surface. Killed bark remains attached, eventually cracking and sloughing off.

DAMAGE: Generally, losses to this disease are small. Mortality is usually limited to seedlings since these cankers are annual and rarely girdle larger trees. Cankers heal completely in most cases, although there is a chance that secondary infections may occur.

REFERENCES: Funk, A. 1969. *Potebniamyces* (*Phacidiella*) disease of the true firs in British Columbia. Canadian Journal of Botany 47: 751-753.

SYDOWIA TIP DIEBACK *Sclerophoma* spp.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: All native conifers.

SIGNS AND SYMPTOMS: Infected trees suffer dieback on leaders and branches. There is often a swelling at the margin of the necrotic and healthy tissue. Small black fruiting structures are produced which are found embedded in the bark of the dead portion of the tree.

DAMAGE: This disease is associated with trees stressed by drought, frost or other factors. Young trees are most often damaged and dead tops or mortality often result.

REFERENCES: Funk, A.; Finck, K.E. 1988. *Sydowia semenospora* sp. nov. and its anamorph on amabilis fir. Canadian Journal of Botany 66: 2128-2129.

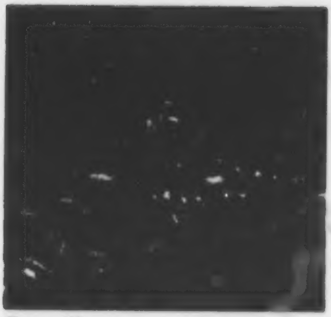


Figure 85.
Branch flagging is typical symptom of RED FLAG DISEASE.

Figure 86.
Cracked bark covering cankers of RED FLAG DISEASE.

Figure 87.
Healed stem canker of SYDOWIA TIP DIEBACK.

Figure 88.
Dead branches of an immature Douglas-fir tree infected with SYDOWIA TIP DIEBACK.

Figure 89.
Black fruiting bodies of SYDOWIA TIP DIEBACK on necrotic bark surface (magnified).

BRANCH/STEM RUSTS

Rusts affecting branches and/or stems are among the most destructive forest diseases in British Columbia. Pine and alternate host species, such as those of the genus Ribes (currants and gooseberries), are infected exclusively. All branch/stem rusts, with the exception of western gall rust, require herbaceous alternate hosts for completion of the life cycle. Aerial invasion of the pine host, by means of fungal spores, can lead to the formation of large blister-like cankers or galls on the main stem or branches if conditions are favorable. As a result, stems and branches are more susceptible to breakage, and trees are weakened or killed due to eventual girdling of the stem by continued canker growth. Foliar attack occurs but is not a significant or accurate identifying feature.

Noticeable disease symptoms appear approximately two to three years after spores have infected the pine host. Discoloration and progressive swelling of the bark becomes apparent, followed by formation of spore blisters in spring of the next year. Further spread occurs by these powdery spores, which are white, yellow or orange and are very apparent. Evidence of animal feeding, roughened bark, and copious resin flow are often seen around the cankers. Tentative identification of branch/stem rust species is possible in the field if the alternate host is present near infected trees. However, microscopic examination of the spores is required for a definitive identification.

Branch/stem rusts, in particular western gall rust and white pine blister rust, spread rapidly and are responsible for serious losses. Generally, seedlings to pole-sized trees have the highest mortality rate but mature trees are also susceptible. Disease spread is more rapid through thinned stands. Branch pruning or eradication of alternate hosts near pine stands are currently the only potentially effective methods for reducing spread. However, only limited success has been obtained with these control methods to date. Development of disease resistant varieties offers some promise in the future. Photographs and descriptions of the important branch/stem rusts follow.

COMANDRA BLISTER RUST *Cronartium comandrae* Pk.
SWEET-FERN BLISTER RUST *Cronartium comptoniae* Arth.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: Lodgepole pine and ponderosa pine.

SIGNS AND SYMPTOMS: Cankers may be on stems or branches. Stem cankers are roughly circular to diamond-shaped. The length of stem cankers caused by comandra blister rust is usually less than four times the width; the length of sweet-fern blister rust stem cankers may be greater than four times the width. Rough bark covers stem cankers, and resin flow may be present near the canker margin. Branch flagging and spike-tops are often associated with stem cankers. Branch cankers appear as galls comprised of swollen bark, in contrast to galls caused by western gall rust, which are woody. White blisters, containing yellow-orange spores, appear on cankers in spring and early summer. Rodents often chew bark in cankered areas and may remove any indication that an infection was present. Secondary insects or fungi may also be associated with cankers. Both rusts have alternate hosts, sweet gale for sweet-fern blister rust and bastard toad-flax for comandra blister rust.

DAMAGE: Stem cankers can cause mortality, growth losses and poor form. If a canker girdles the stem, and if enough crown to support the tree exists below the canker, top mortality (spike-top) will result. The entire tree may die if insufficient crown is present below the girdled area. Seedling to juvenile and overmature trees suffer the most damage from cankers. Infections occur erratically among geographic regions and within stands due to variations in distribution of the alternate hosts, climate, and susceptibility of the tree species and individual trees.

REFERENCES: Anderson, G.W. 1970. Sweetfern rust on hard pines. U.S.D.A. Forest Service. Forest Pest Leaflet 79. 6p.

Johnson, D.W. 1986. Comandra blister rust. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 62. 8p.

Lowe, D.P.; Ziller, W.G. 1977. Stem rusts of pine in western Canada. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 37. 10 p.

Figure 90.
Diamond-shaped stem canker of COMANDRA BLISTER RUST.

Figure 91.
SWEET-FERN BLISTER RUST canker girdling host stem. Note white blisters which contain yellow-orange spores.

Figure 92.
Rough bark and resin flow are associated with COMANDRA and SWEET-FERN BLISTER RUSTS. Note swollen bark at canker margin.

ORANGE STALACTIFORM BLISTER RUST *Cronartium coleosporioides* Arth.
Previously *Peridermium stalactiforme* Arth. and Kern

DISTRIBUTION: Throughout British Columbia.

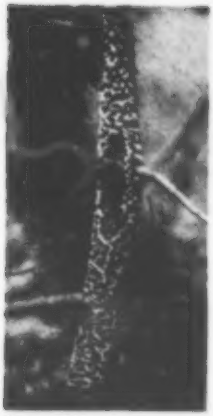
TREE SPECIES ATTACKED: Lodgepole pine.

SIGNS AND SYMPTOMS: Resinous stem and branch cankers, with associated branch flagging, are produced. On smaller stems and branches cankers are spindle-shaped with swollen bark. Cankers on older trees are elongate, diamond-shaped, and may be greater than 9 m long. The width of the cankers is only about one tenth the length. Canker faces are yellow. Rodents feed on cankered bark, causing small dark ridges. This gives the bark surrounding stem cankers a rough appearance. In the absence of severe rodent feeding, white blisters containing orange-yellow spores are usually produced near the canker margin in spring or early summer. Secondary insects or fungi may also be associated with cankers. This disease has two alternate hosts: indian paintbrush and cow-wheat.

DAMAGE: Mortality, resulting from girdling by stem cankers, may occur on young trees but a single stem canker usually will not girdle a larger tree. Resin-impregnated sunken or flat areas and sweep of the bole are more typical results of stem cankering. Cankers may predispose trees to snow breakage. Infections occur erratically among geographic regions and within stands due to distribution of the alternate hosts, climate, and susceptibility of the tree species and individual trees.

REFERENCES: Lowe, D.P.; Ziller, W.G. 1977. Stem rusts of pine in western Canada. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 37. 10 p.

Mielke, J.L. 1956. The rust fungus (*Cronartium stalactiforme*) in lodgepole pine. Journal of Forestry 54: 518-521.



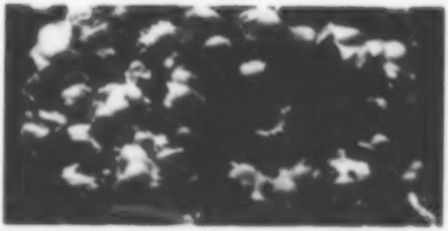


Figure 94
Blisters of ORANGE STALACTIFORM BLISTER RUST contain orange spore masses.

Figure 93
Elongate ORANGE STALACTIFORM BLISTER RUST stem canker

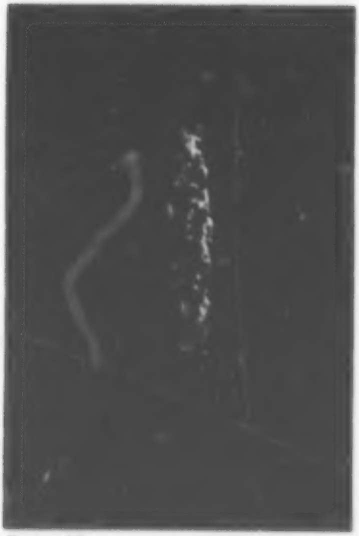


Figure 95.
Branch canker caused by ORANGE STALACTIFORM BLISTER RUST infection.

WESTERN GALL RUST *Endocronartium harknessii* (J.P. Moore) Y. Hirat.

DISTRIBUTION: Throughout the range of two- or three-needled pines in British Columbia.

TREE SPECIES ATTACKED: Lodgepole pine and ponderosa pine.

SIGNS AND SYMPTOMS: This disease produces easily recognizable galls, on branches or stems, which are roughly spherical or pear-shaped. The galls are woody and grow in size each year unless girdling occurs, which will kill the tree distal to the gall. Some large stem galls live for decades and produce a lesion called a hip canker which can kill a branch or the entire tree. Galls require two to four years to mature at which time they release orange spores from early May to late June. The spores are released from fissures in the bark covering the galls. These spores can directly infect other pines. In contrast, the other rust fungi which attack pines in British Columbia require an alternate host to complete their life cycle. There is great variability in susceptibility to this disease among trees of the same species.

DAMAGE: Mortality from this disease is uncommon, occurring only occasionally in an infected area. Mortality results from complete girdling by stem cankers, or wind breakage at canker-weakened points. The majority of damage involves growth reduction resulting from branch cankers and a reduction in timber value due to defects caused by stem cankers. Low incidence of branch cankers should not seriously affect the growth of a tree. Vigorously growing trees are more vulnerable to infection. This disease occurs more often in open growing or spaced stands than in dense stands.

REFERENCES: Bella, I.E. 1985. Pest damage incidence in natural and thinned lodgepole pine in Alberta. Forestry Chronicle 61: 233-238.

Lowe, D.P.; Ziller, W.G. 1977. Stem rusts of pine in western Canada. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 37. 10 p.

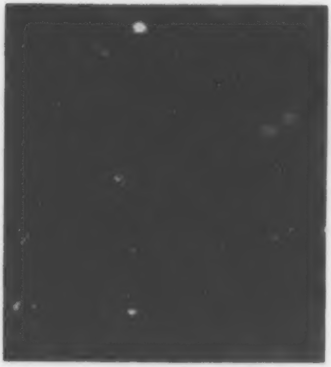


Figure 96
Spherical gall of WESTERN GALL RUST
Orange spores are being released

Figure 97
Lodgepole pine with multiple galls from extensive WESTERN GALL RUST infection

Figure 98
Old stem canker of WESTERN GALL RUST. Note roughened surface of bark.

Figure 99
Symptoms resulting from complete girdling by WESTERN GALL RUST.

WHITE PINE BLISTER RUST *Cronartium ribicola* J.C. Fisch

DISTRIBUTION: Throughout the range of the hosts.

TREE SPECIES ATTACKED: Western white pine, limber pine, whitebark pine.

SIGNS AND AND SYMPTOMS: This is the only stem rust occurring on western white pine in British Columbia. Branch flagging, caused by cankers girdling the branches, is evident throughout the year. Cankers are produced on branches and stems, usually within 2.5 m of the ground. Thus, initial infection occurs mainly on younger trees with branches close to the ground. Cankers begin as yellowish orange swellings. Cankers usually have a diamond shape on stems with smooth bark. The length of stem cankers is less than four times the width. In August, young cankers produce drops of honey-colored liquid from the swollen area. This liquid is often eaten by insects. White blisters, which rupture to expose orange spores, are produced on the cankers in spring and early summer. As cankers age, the bark covering them becomes dark, rough, swollen, and colonized by secondary insects and fungi. Rodents feed on the resinous areas surrounding cankers. Alternate hosts are species of *Ribes* (currants and gooseberries).

DAMAGE: Tree mortality, spike-top and branch mortality can occur as a result of infection. Tree mortality may reach 90% of white pine in a stand. Infection levels are higher near plants of the genus *Ribes*. Trees growing on steep slopes tend to have cankers higher up the stem.

REFERENCES: Hunt, R.S. 1983. White pine blister rust in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 26. 7p.

Hunt, R.S.; Meagher, M.D. 1985. How to recognize white pine blister rust cankers. Canadian Forestry Service, Pacific Forest Research Centre. Fact Sheet.

Figure 100.
WHITE PINE BLISTER RUST cankers are found on stems and branches. Note diamond shape.

Figure 101.
Yellowish orange bark discoloration precedes formation of WHITE PINE BLISTER RUST cankers.

Figure 102.
Old WHITE PINE BLISTER RUST infections are characterized by rough, swollen bark.

Figure 103.
Developing WHITE PINE BLISTER RUST canker. Note shape, color and resin flow.

Figure 104.
Top killed by WHITE PINE BLISTER RUST.

BROOM RUSTS

Broom rusts cause conspicuous branch brooms on their coniferous hosts. These fungi require an alternate herbaceous host for completion of their life cycle but are capable of spreading within the primary host branches without further infection. Thus, new needles are infected each year, resulting in conspicuous yellowish to orange witches' brooms. The discoloration is due to dying and dead foliage and the presence of fungal spore masses on the needles. Dead branches, stem deformity, and growth reduction occur. Mortality is not common but trees infected by broom rust disease are subject to breakage or attack by insects and other diseases. Pruning or removal of infected trees and alternate hosts are presently the best control methods. Descriptions of the most important members of this group follow.

FIR BROOM RUST *Melampsorella caryophyllacearum* Schroet.

DISTRIBUTION: Throughout British Columbia.

TREE SPECIES ATTACKED: All native true firs of any age.

SIGNS AND SYMPTOMS: Distinctive greenish yellow, upright brooms are visible in summer. The color of these brooms contrasts with the strong green of healthy needles on the same tree. Broom needles are pale yellow, shorter and thicker than normal needles and are arranged in a spiral. In summer, these needles are covered with blisters filled with yellow or orange spores. The broom needles are cast in the fall and a new flush appears in the spring. Portions of branches and trunks associated with brooms are deformed by swelling, galls and cankers.

DAMAGE: In British Columbia damage has been light; however, volume loss, growth reduction, and mortality occur as a result of this disease. Volume loss results from trunk swellings, cankers and spike-tops. Growth reduction results from decreased productive crown, and direct mortality may result from excessive numbers of brooms. Indirect mortality may result from attacks by secondary insects or wind breakage in the area of a stem canker.

REFERENCES: Baranyay, J.A., Ziller, W.G. 1972. Broom rusts of conifers in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 48. 6p.

Peterson, R.S. 1964. Fir broom rust. U.S.D.A. Forest Service. Forest Pest Leaflet 87. 6p.

Figure 105.
Discolored upright broom caused by FIR BROOM RUST.

Figure 106.
FIR BROOM RUST infection in fall. Note necrotic needles which are cast annually.

Figure 107.
Typical short yellow needles found on FIR BROOM RUST brooms.

SPRUCE BROOM RUST *Chrysomyxa arctostaphyli* Diet.

DISTRIBUTION: Throughout British Columbia.

TREE SPECIES ATTACKED: All native spruce species.

SIGNS AND SYMPTOMS: Conspicuous orange-yellow brooms are apparent in the summer months. The discolored needles are shed in fall and a new flush of pale yellow needles is produced the following spring. The needles of spruce brooms caused by other agents remain a normal color and are not cast in the fall. Closer examination of broom needles will reveal small orange-yellow blisters filled with spores. Brooms caused by this disease grow perennially and may be greater than 30 years old.

DAMAGE: Tree form can be affected by this disease, including the production of spike-tops, dead branches and stem deformation. This disease may also cause growth reduction and predispose trees to decay fungi. Mortality is sometimes associated with this disease.

REFERENCES: Baranyay, J.A.; Ziller, W.G. 1972. Broom rusts of conifers in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 48. 6p.

Figure 108.
Needles infected with SPRUCE BROOM RUST showing small spore laden blisters.

Figure 109.
Older orange-yellow broom of SPRUCE BROOM RUST. Deformity and growth reduction are common.

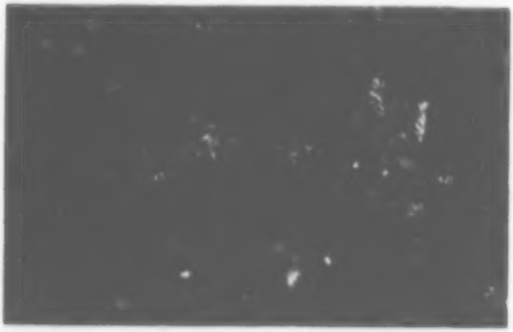


Figure 110.
Developing SPRUCE BROOM RUST broom. Growth is perennial.

DWARF MISTLETOES

Dwarf mistletoes are very common and destructive parasites of lodgepole pine, Douglas-fir, western hemlock and western larch. Other pine species, true firs and spruce are usually only secondary hosts. One species, hemlock dwarf mistletoe, is restricted to coastal British Columbia while lodgepole pine, Douglas-fir, and larch dwarf mistletoes are found only in interior British Columbia. Dwarf mistletoes are perennial parasitic flowering plants that derive moisture and nutrition from their host and produce distinctive aerial shoots. These aerial shoots can be used to identify each species and to distinguish dwarf mistletoe-caused damage from similar injury due to fungal diseases.

Swellings of the branches and main stem and witches' brooms develop as the dwarf mistletoes grow within host tissue. The characteristic shape and extent of these swellings and witches' brooms is dependent upon the particular host-parasite relationship. Generally, symptoms are distinctive on the preferred hosts but may vary on secondary hosts. Nevertheless, the results of prolonged infection are similar from one host species to the next. Moderately to severely infected trees have significantly reduced wood quality and volume, and infected stands have a high incidence of mortality.

Tree-to-tree spread of dwarf mistletoe is accomplished by the production of sticky seeds which are disseminated by forceful ejection from the parent plant. Most seeds remain very close to the host; thus, the rate of disease spread is slow. However, 10 dwarf mistletoe-infected residual trees can infect an entire hectare of new plantation within 15 years of harvest since there is a very high incidence of disease spread from overstory to understory trees. Thus, damage is correlated with the proximity and height of infected residual trees, the stand density and height of regeneration trees and slope. On some sites trees are only slightly damaged and appear to outgrow the mistletoe. In other situations, especially open-growing stands on poor sites, damage is severe. The most effective control is to remove all infected trees at the time of harvest. However, successful management requires accurate identification of each dwarf mistletoe species. Descriptive text and photographs of the most important mistletoe species follow.

DOUGLAS-FIR DWARF MISTLETOE *Arceuthobium douglasii* Engelmann

DISTRIBUTION: The interior of British Columbia restricted to the southern interior range of the preferred host.

TREE SPECIES ATTACKED: Douglas-fir is preferred. Grand fir and interior spruce are occasionally attacked. This is the only dwarf mistletoe species that frequently attacks Douglas-fir. Trees of all sizes and ages are attacked.

SIGNS AND SYMPTOMS: Very large, drooping witches' brooms commonly form on Douglas-fir. These brooms may attain 5-10 m or more in vertical dimension on some open-grown trees. Brooms are generally more numerous in the lower crown. Broomed branches have smaller, lighter colored needles than normal branches. In addition, infected branches have spindle-shaped swellings with well anchored mistletoe aerial shoots that are 1-2 cm in length, square in cross-section, slender, and olive green. Aerial shoots of this species have relatively few branches and produce green berries which contain sticky seeds. Small basal cups remain on the bark after disintegration of the aerial shoots. Stem infections are characterized by large elongated and flattened cankers, or by spindle-shaped swellings of the stem. The stem may also have small individual burls as a result of numerous infection sites.

DAMAGE: Douglas-fir dwarf mistletoe infection causes reduced vigor, height and radial increment. Infection also lowers wood quality due to stem infection, and increases the probability of infection by secondary fungal pathogens. Spike-tops and mortality are common. Infected trees growing in more open stands are more severely damaged.

REFERENCES: Graham, D.P. 1961. Dwarf mistletoe of Douglas-fir. U.S.D.A. Forest Service. Forest Pest Leaflet 54. 4 p.

Smith, R.B. 1972. Relation of topography and vegetation to the occurrence of Douglas-fir dwarf mistletoe at its northern limits in British Columbia. Ecology 53: 729-734.

Figure 111.
Developing aerial shoots of DOUGLAS-FIR DWARF MISTLETOE.

Figure 112.
Drooping branch due to heavy DOUGLAS-FIR DWARF MISTLETOE infection.

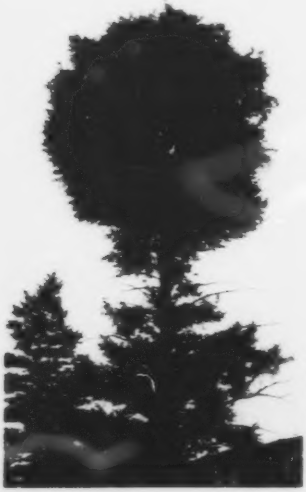


Figure 113.
Severely deformed crown resulting from extensive DOUGLAS-FIR DWARF MISTLETOE infection.

HEMLOCK DWARF MISTLETOE *Arceuthobium tsugense* (Rosendahl) G.N. Jones

DISTRIBUTION: Follows the coastal range of western hemlock. Not found in interior British Columbia.

TREE SPECIES ATTACKED: Western hemlock is primarily attacked. Sitka spruce, grand fir and amabilis fir are occasionally attacked. Rarely, lodgepole pine is infected by a shore pine race of *A. tsugense* on the south coast.

SIGNS AND SYMPTOMS: Infected branches usually occur in dense clumps and are characterized by extreme spindle-shaped swellings and witches' brooms. Witches' brooms of this species generally grow horizontally with little branch drooping. Pronounced stem swellings also occur on trees of all age classes. Mistletoe aerial shoots are produced only on the swollen portions of branches and stems, and are anchored in the host tissue. In dense stands, these shoots may be absent in the shaded lower crown. Hemlock dwarf mistletoe aerial shoots are arranged in a fan-like pattern, with several shoots emerging at a node, and are square in cross-section. They are perennial, green, average about 5-12 cm long, and produce green berries containing sticky seeds. Small basal cups remain on the bark after disintegration of these shoots.

DAMAGE: Hemlock dwarf mistletoe is a wide-spread, very damaging parasite in coastal western hemlock stands. Infected trees exhibit significantly reduced growth which is often noticeable by 20 years of age. By 40 years of age, the volume of moderately to severely infected trees is 20-40% less than the volume of adjacent uninfected or lightly infected trees. All infection sites offer entry points for secondary pathogens. In addition, stem swellings adversely affect wood quality due to deformity and breakage. Early mortality may result from prolonged infection.

REFERENCES: Alfaro, R.I.; Bloomberg, W.J.; Smith, R.B. 1985. Epidemiology of dwarf mistletoe in western hemlock stands in south coastal British Columbia. Canadian Journal of Forest Research 15: 909-913.

Muir, J.; ed. 1985. Proceedings of a workshop on management of hemlock dwarf mistletoe. B.C. Ministry of Forests. Pest Management Report 4. 58p.

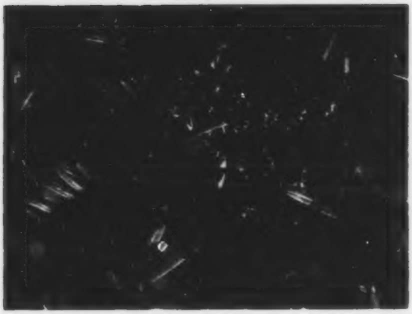


Figure 114.
HEMLOCK DWARF MISTLETOE aerial shoots. Note spindle-shaped branch swelling.

Figure 115.
Swelling on bole of western hemlock caused by HEMLOCK DWARF MISTLETOE.

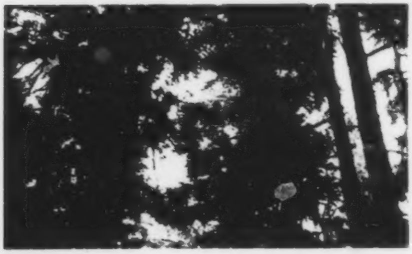


Figure 116.
Typical witches' brooms resulting from prolonged HEMLOCK DWARF MISTLETOE infection.

LARCH DWARF MISTLETOE *Arceuthobium laricis* (Piper) St. John

DISTRIBUTION: In the south eastern interior of the province following the range of western larch.

TREE SPECIES ATTACKED: Western larch is the preferred host. Lodgepole pine, western white pine, subalpine and grand fir, and interior spruce are occasionally attacked.

SIGNS AND SYMPTOMS: Infected branches and stems are usually very swollen. Witches' brooms are dense and upright and have branches that are very swollen near the base. Mistletoe aerial shoots or their remnants (basal cups) are confined to and anchored in these swollen areas. Aerial shoots of this species are 2-3 cm long, square in cross-section, purplish green in color, and are fan-like in arrangement where branched. Green berries, which contain sticky seeds, are produced at the shoot tips. Open-grown larch trees occasionally form dense brooms caused by adventitious branching but these will lack the diagnostic mistletoe shoots and swellings. Lodgepole pine and larch dwarf mistletoes sometimes infect trees on the same site. However, lodgepole pine dwarf mistletoe can be distinguished from larch dwarf mistletoe by the whorled branching pattern of its aerial shoots and round cross-sectional shape.

DAMAGE: Larch dwarf mistletoe causes reduced volume and wood quality. Mortality and spike-top occur after prolonged infection. Incidence of infection on immature trees may be less than for lodgepole pine or hemlock dwarf mistletoe because of the deciduous nature of larch.

REFERENCES: Smith, R.B. 1974. Infection and development of dwarf mistletoes on plantation-grown trees in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-97. 21 p.

Figure 117.
Branch swelling and aerial shoots of LARCH DWARF MISTLETOE.

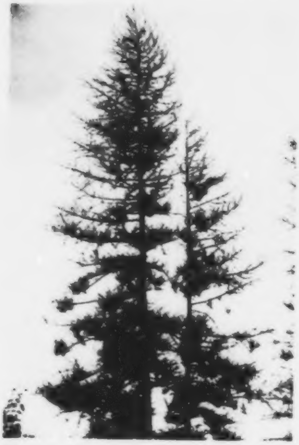


Figure 118.
Typical upright witches' brooms of LARCH DWARF MISTLETOE.

Figure 119.
LARCH DWARF MISTLETOE infection showing thin crown and deformity. Tree vi[illegible] is greatly reduced.

Figure 120.
Basal cups of LARCH DWARF MISTLETOE remain after aerial shoots have disintegrated.

LODGEPOLE PINE DWARF MISTLETOE *Arceuthobium americanum* Nutt. ex Engelmann

DISTRIBUTION: Throughout the range of lodgepole pine in interior British Columbia. Lodgepole pine dwarf mistletoe has the greatest range of the province's dwarf mistletoe species.

TREE SPECIES ATTACKED: Lodgepole pine is the preferred host. Ponderosa pine is occasionally attacked, and interior spruce and Douglas-fir are rare hosts.

SIGNS AND SYMPTOMS: Infected branches and stems are usually only slightly swollen. Witches' brooms are characterized by long, slender, rigidly upright branches which are sparsely foliated with short needles. Exposure brooms, which superficially resemble witches' brooms, occasionally occur on open-growing pine. However, these exposure brooms can be distinguished from actual dwarf mistletoe infection since they grow in a more horizontal fashion, are densely foliated, and lack aerial shoots.

Mistletoe aerial shoots or their remnants (basal cups) are firmly anchored in infected stems and branches. They initially appear close to the branch tips with proliferation of shoots then proceeding to older portions of the infected branches. Lodgepole pine dwarf mistletoe aerial shoots are arranged in a whorled pattern, with several shoots emerging at a node. This branching pattern distinguishes lodgepole pine dwarf mistletoe aerial shoots from the other mistletoe species. In addition, the aerial shoots are round in cross-section, yellow-green, 3-12 cm in length, and produce green berries which contain sticky seeds.

DAMAGE: This species causes widespread, significant damage in interior lodgepole pine stands. Brooming is particularly severe in more open stands. Trees infected when immature are either prematurely killed or never attain a merchantable size. At age 60 years or older, moderately to severely infected trees have 15-30% less volume than adjacent lightly infected or uninfected trees. Stem infection reduces wood quality due to deformity and canker formation. Spike-tops commonly occur.

REFERENCES: Baranyay, J.A.; Smith, R.B. 1972. Dwarf mistletoes in British Columbia and recommendations for their control. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-72. 18p.

Van Sickle, G.A.; Wegwitz, E. 1978. Silvicultural control of dwarf mistletoe in young lodgepole pine stands in Alberta and British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-180. 11 p.

Figure 121.
Aerial shoots of LODGEPOLE PINE DWARF MISTLETOE.

Figure 122.
LODGEPOLE PINE DWARF MISTLETOE aerial shoots showing green berries which contain sticky seeds.

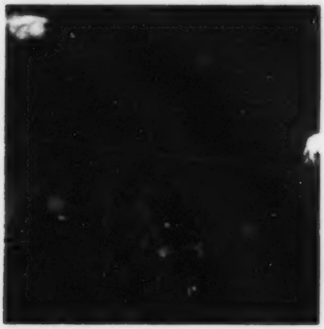


Figure 123.
Lodgepole pine severely infected with LODGEPOLE PINE DWARF MISTLETOE. Compare distorted crown (left) with healthy crown (right).

NEEDLE CASTS, BLIGHTS AND RUSTS

Needle casts and blights are fungal diseases which kill and/or cause premature casting of needles from coniferous trees. The difference between a cast and a blight is that needle cast fungi attack only needles of the current year's growth although symptoms may take a year to develop. Blight fungi, on the other hand, are found on any-aged needle. All conifers native to British Columbia are attacked by some type of needle cast or blight. Some species, such as the pines, are attacked by many needle casts, blights or rusts, and others such as western red cedar are attacked by few.

Needle cast and blight fungi generally infect only needles (one exception is Elytroderma disease) and therefore cause defoliation. Damage resulting from defoliation of any type can range from no apparent harm to mortality. Many factors are involved including age (young trees are always more susceptible to damage from defoliation than older trees), degree of defoliation, species of tree, pre-defoliation tree health, present growing conditions and the presence of secondary organisms which attack stressed trees. Outbreaks of needle casts and blights fluctuate greatly from year to year, depending mostly on weather conditions which affect spore production, release and germination.

Needle rusts are common to all conifers in British Columbia. They have complex life cycles which usually involve an alternate host which may be a fern, flowering plant or shrub. Most infections occur on young trees or on the lower branches of older trees. Infections are confined to individual needles, which usually die and are cast. Damage from these diseases varies from possible growth reduction on younger trees to no apparent effects on older trees. Needle rusts are most visible in the spring when easily recognizable fruiting structures are produced on the needles of coniferous hosts. These are typically blister-like sacs filled with white to orange spores. Many species of needle cast, blight and rust fungi infect the conifers of British Columbia. However, only those which are most common or likely to cause significant damage will be described individually. Descriptions and photographs of needle casts, blights and rusts follow.

CEDAR LEAF BLIGHT *Didymascella thujina* (Durand) Maire
Previously *Keithia thujina* Durand

DISTRIBUTION: Throughout the province, following the range of western red cedar.

TREE SPECIES ATTACKED: Western red cedar.

SIGNS AND SYMPTOMS: Infected leaves turn reddish brown over the summer. In fall, some infected leaf twigs are shed. Older twigs still attached to the branch become ashy gray. Infections are most common on leaves of lower branches. The upper crown may sustain a lesser degree of infection. Small black cavities will be found on the upper surfaces of infected leaves. These holes are left after the fruiting bodies dry up and fall out. The holes could easily be mistaken for insect feeding punctures. Dense stands growing on wetter sites are most affected.

DAMAGE: Overall losses from this disease are low, although seedlings and saplings may suffer mortality. Older trees may exhibit growth reduction, dead branches and occasional mortality.

Figure 124.
Western red cedar branchlets infected with CEDAR LEAF BLIGHT.

Figure 125.
Holes left by CEDAR LEAF BLIGHT fruiting bodies.

Figure 126.
Developing fruiting structures produced by CEDAR LEAF BLIGHT.

DOUGLAS-FIR NEEDLE CAST *Rhabdocline pseudotsugae* Syd

DISTRIBUTION: Throughout the range of Douglas-fir

TREE SPECIES ATTACKED: Douglas-fir from seedling up to 30 years of age. Older trees can be attacked but damage is usually minimal.

SIGNS AND SYMPTOMS: The first symptom is pale yellow spots on needles, most commonly near the tips, in the fall or early winter. By the following spring these spots change to reddish brown and are in sharp contrast to the rest of the needle which remains green. At this stage infected needles appear mottled and during severe infestations trees appear scorched. Needle mottling from this disease may be distinguished from that caused by cooley spruce gall adelgid because these insects produce smaller patches of chlorosis throughout the growing season. Also, needles attacked by cooley spruce gall adelgid are often distorted, and signs of the insect are usually present. Fruiting structures of Douglas-fir needle cast develop in late May or June, usually on the lower surface of the needle. The fruiting structures are small swellings at first. Later, the needle epidermis ruptures in an irregular longitudinal split to expose the brownish fruiting structure. Infected needles are shed soon after the appearance of fruiting bodies. This disease is most prevalent during periods of moist climatic conditions. Dense, pure stands are most susceptible to infection although tree suppression is apparently not a factor.

DAMAGE: Repeated heavy infections can completely defoliate trees, with the exception of current needles. In some cases mortality or substantial growth reduction result.

REFERENCES: Collis, D.G. 1971. Rhabdocline needle cast of Douglas-fir in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 32. 4p.

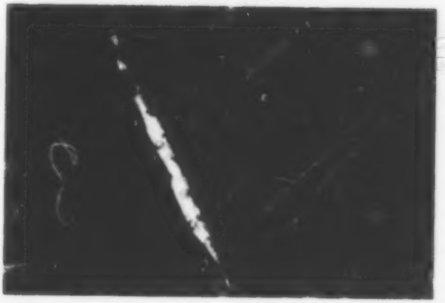


Figure 127.
Red discoloration of needles due to DOUGLAS-FIR NEEDLE CAST infection of previous year

Figure 128.
Ruptured needle epidermis exposing brown elongated fruiting body of DOUGLAS-FIR NEEDLE CAST.

Figure 129.
Current needles do not show symptoms of DOUGLAS-FIR NEEDLE CAST infection.

Figure 130.
Discoloration and defoliation due to DOUGLAS-FIR NEEDLE CAST.

ELYTRODERMA DISEASE *Elytroderma deformans* (Weir) Darker

DISTRIBUTION: Throughout the range of ponderosa pine.

TREE SPECIES ATTACKED: Ponderosa pine and lodgepole pine.

SIGNS AND SYMPTOMS: Needles infected the previous year initially turn bright red but fade to a straw color. On lodgepole pine, occasional gray coloration occurs. Infected pine needles are cast in early fall for ponderosa pine and late fall for lodgepole pine. Thin crowns often result from needle casting, and lions' tails may be observed. Infection can produce brooms with upturned thickened twigs on ponderosa pine. Shoots supporting brooms have brown necrotic lesions in the inner bark. Needles discolored from infection may display fruiting bodies in spring. Fruiting bodies begin as faint, narrow lines on the outer surface of infected needles, and blacken by late spring or early summer. Infection may be greater on moist sites such as valley bottoms or lake shores.

DAMAGE: This fungus is atypical of needle cast fungi occurring on British Columbia conifers because it can spread from needles to shoot tissue. This characteristic results in broom formation, and allows the fungus to survive periods of climate unfavorable for spore release. Light infection of less than 25% of the needles causes little damage. Severe infection will produce thin, ragged crowns and growth reduction. Tree or lower crown mortality can result from severe defoliation. Heavy infection can also predispose trees to attacks by other pathogenic fungi, or insects. Younger trees are affected to a greater extent than older trees.

REFERENCES: Hunt, R.S. 1978. Elytroderma disease of pines. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 27. 4p.

Hunt, R.S. 1986. Pine needle casts and blights in the Pacific region. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 43. 7p.

Figure 131.
Discolored needles and narrow black fruiting bodies typical of ELYTRODERMA DISEASE.

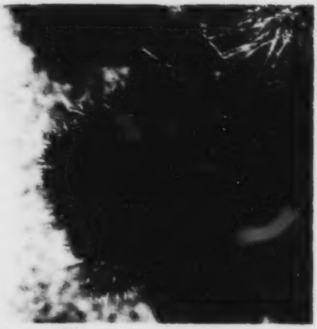


Figure 132.
Upturned broom on ponderosa pine caused by ELYTRODERMA DISEASE.

Figure 133.
Lion's tails and dead foliage resulting from ELYTRODERMA DISEASE.

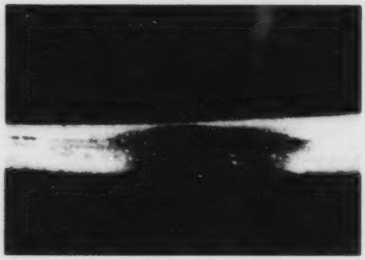


Figure 134.
Ruptured needle with black elongated fruiting structure of ELYTRODERMA DISEASE.

FIR-FIREWEED RUST *Pucciniastrum epilobii* Otth.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: True firs, especially subalpine fir.

SIGNS AND SYMPTOMS: Small blisters filled with white or yellow spores develop on the lower side of current year's needles in late spring to early summer. Fireweed is the alternate host for this disease.

DAMAGE: Severe infection can cause almost complete defoliation of the current year's needles. Growth reduction may result but mortality is rare.

REFERENCES: Bauman, N.G.; Wegwitz, E. 1972. Needle rusts of the true firs in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 45. 11p.

LARCH NEEDLE BLIGHT *Hypodermella laricis* Tub.

DISTRIBUTION: Southeastern British Columbia.

TREE SPECIES ATTACKED: Western larch.

SIGNS AND SYMPTOMS: Infections commence in spring. Initial infection causes needle droop and premature color change from green to reddish brown, usually in June. A severely infected stand develops a scorched appearance. The entire crown may be affected on small trees; infections in older trees are usually more prominent in the lower crown. Infected needles remain attached to the spur shoots for up to two years after healthy foliage is shed in the fall. Black fruiting bodies soon appear on infected needles. They are oblong or elliptical in early summer and become longer, with a split down the middle, in late summer. This disease may occur concurrently with larch needle cast.

DAMAGE: This disease infects only needles; however, spur shoots may die after successive severe defoliations. Branches with high spur shoot mortality may be killed as a result. Tree mortality is possible, particularly in young trees. Repeated infections of the same tree are uncommon. Western larch usually produces a full crown in the spring following an infection. Therefore, damage is usually limited to minor growth reduction.

REFERENCES: Dubreuil, S.H. 1982. Western larch needle blight and needlecast in the northern region. U.S.D.A. Forest Service. Northern Region Report 82-9. 14p.

Garbutt, R.W. 1984. Foliage diseases of western larch in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 71. 4p.

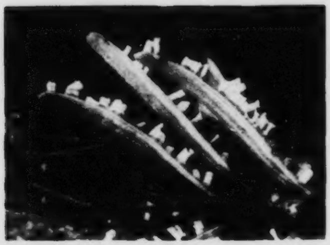


Figure 135.
Blisters containing white to yellow spores of FIR-FIREWEED RUST.

Figure 136.
Current growth killed due to infection by FIR-FIREWEED RUST.

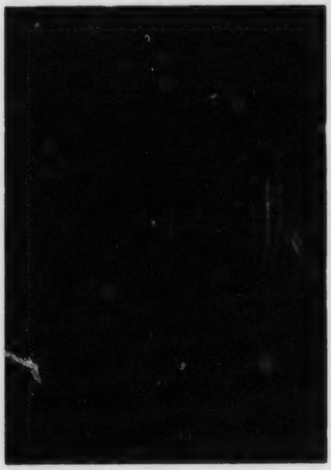


Figure 137.
Necrotic needles resulting from LARCH NEEDLE BLIGHT. Note black fruiting bodies.

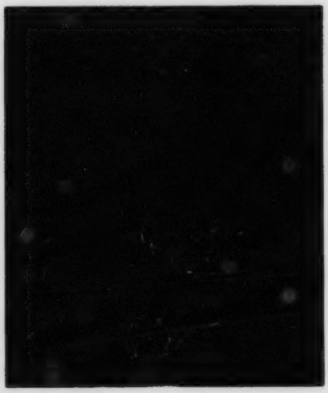


Figure 138.
LARCH NEEDLE BLIGHT on young larch. Infected needles remain attached after healthy needles are shed.

LARCH NEEDLE CAST *Meria laricis* Vuill.

DISTRIBUTION: Southeastern British Columbia.

TREE SPECIES ATTACKED: Western larch.

SIGNS AND SYMPTOMS: Needles of the lower crown are most heavily attacked. The middle or tip of a needle is initially infected. This area turns yellow, wilts, and becomes reddish brown soon after. The infection and accompanying discoloration eventually cover the entire needle. Most needles are shed in May or June within weeks of infection. However, needle casting can occur throughout the growing season. In contrast, larch needle blight infections occur only in spring, producing visible fruiting bodies, and most infected needles are retained. Larch needle cast and larch needle blight commonly occur together.

DAMAGE: A single heavy defoliation will cause only minor growth reduction in larger trees; however, young trees may suffer mortality. Significant mortality has occurred in forest nurseries. Repeated infections, although uncommon, can cause mortality in older trees. Infections predispose trees to damage by other agents, such as root diseases or abiotic disorders.

REFERENCES: Dubreuil, S.H. 1982. Western larch needle blight and needlecast in the northern region. U.S.D.A. Forest Service. Northern Region Report 82-9. 14p.

Garbutt, R.W. 1984. Foliage diseases of western larch in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 71. 4p.

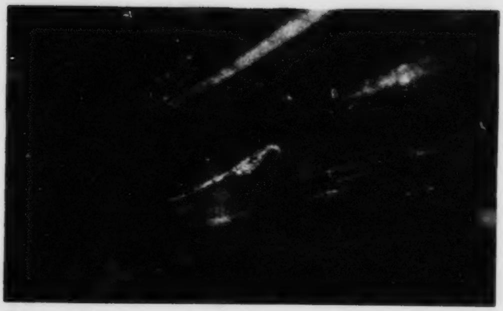


Figure 139.
Discoloration of needles caused by LARCH NEEDLE CAST. Initial infection is near middle or tip and fruiting bodies are not visible.

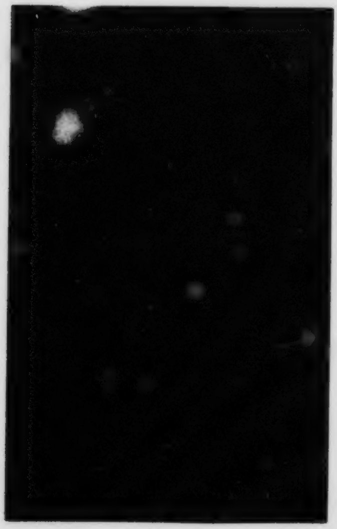


Figure 140.
Wilted reddish brown needles symptomatic of LARCH NEEDLE CAST infection.

LARGE-SPORED SPRUCE-LABRADOR TEA RUST *Chrysomyxa ledicola* Lagerh.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: All native spruce.

SIGNS AND SYMPTOMS: The current year's needles develop prominent white blisters filled with bright orange spores. The areas on the needle where blisters originate are chlorotic and contrast with the remaining healthy green portions.

DAMAGE: Current year's needles may be almost completely defoliated. Growth loss may result but mortality is rare. This rust is most severe adjacent to bogs where the alternate host (Labrador tea) is found, and during periods of moist weather.

REFERENCES: Hennon, P.E. Spruce needle rust. U.S.D.A. Forest Service. Alaska Region Leaflet R10-TP-4. 6p.

PINE NEEDLE CAST *Lophodermella concolor* (Dearn.) Darker

DISTRIBUTION: Throughout the host range.

TREE SPECIES ATTACKED: Lodgepole pine.

SIGNS AND SYMPTOMS: Infected needles turn reddish brown in May or June. In July, needles become straw-colored. Concurrently, fruiting structures form which have the same color as the surrounding needle surface. Thus, fruiting bodies of pine needle cast are difficult to see. Symptoms of this disease are similar to those of *Elytroderma deformans* infection; however, fruiting structures produced by *Elytroderma deformans* disease are much more visible.

DAMAGE: This disease can cause severe defoliation. Growth reduction and mortality may result. However, climatic conditions required for extensive defoliation seldom occur in successive years.

REFERENCES: Hunt, R.S. 1986. Pine needle casts and blights in the Pacific region. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 43.7p.

Figure 141.
LARGE-SPORED SPRUCE-LABRADOR TEA RUST infection is restricted to new foliage.

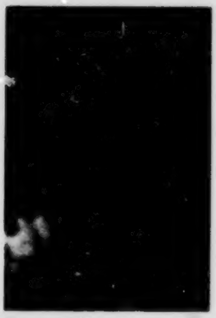


Figure 142.
White blisters of LARGE-SPORED SPRUCE-LABRADOR TEA RUST on current year's needles. Note chlorosis around blisters.

Figure 143.
Discolored needles and black fruiting bodies resulting from PINE NEEDLE CAST infection.

Figure 144.
Needle rupturing caused by PINE NEEDLE CAST infection. Fruiting bodies are inconspicuous.

RED BAND NEEDLE DISEASE *Scirrhia pini* Funk and Parker

Previously *Dothistroma pini* Hulb.

DISTRIBUTION: Throughout the province, following the range of pine.

TREE SPECIES ATTACKED: Native and non-native pines.

SIGNS AND SYMPTOMS: Infected needles display small chlorotic bands or spots in the fall. Needle tissue distal to chlorotic areas becomes necrotic two to three weeks following infection. Distinctive red bands are formed in the discolored area during spring. Small black fruiting bodies are revealed if the outer layer or epidermis of the needle is ruptured. Infected needles are shed in summer or fall, producing thin crowns in infected stands. Infections generally occur in the lower crown and on older needles. Needles of all ages may be infected, although infections are not uniform throughout the crown. Young trees are more commonly attacked than older trees.

DAMAGE: Red band needle disease causes damage to pines worldwide. Exotic pine species planted in British Columbia have sustained heavy losses from this disease. Native pine species are relatively resistant, although there have been cases of mortality in young stands. Severe defoliation from repeated attacks causes growth reduction.

REFERENCES: Hunt, R.S. 1986. Pine needle casts and blights in the Pacific region. Canadian Forestry Service, Pacific Forestry Centre. Forest Pest Leaflet 43. 7p.

Peterson, G.W. 1982. Dothistroma needle blight of pines. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 143. 6p.

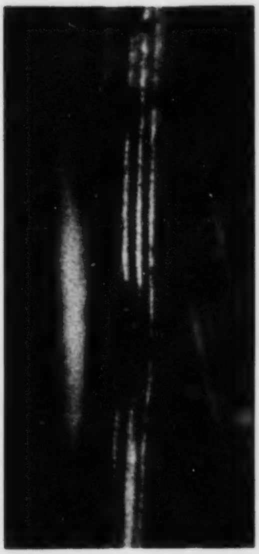


Figure 145.
Black elliptical fruiting bodies of RED BAND NEEDLE DISEASE on ponderosa pine needles.

Figure 146.
Necrotic needle tips produced by RED BAND NEEDLE DISEASE.

Figure 147.
Thin discolored crowns seen with advanced stage of RED BAND NEEDLE DISEASE.

SIROCOCCUS TIP BLIGHT *Sirococcus strobilinus* Preuss

DISTRIBUTION: Coastal British Columbia.

TREE SPECIES ATTACKED: Western hemlock, spruce and pines. Other conifers are very rarely attacked .

SIGNS AND SYMPTOMS: The current year's needles on the terminal and lateral tips become brown. Shoots eventually die, at which time small purplish cankers should be visible on the stem. Dead tips are usually curled back into a shepherd's crook. Small black fruiting bodies may be visible on dead stems or needles. Infection is usually restricted to the current year's growth.

DAMAGE: This disease is more common in dense regeneration, or stands where low light and high moisture conditions prevail. Under these conditions, seedlings and young trees may suffer mortality as a result of multiple infections. Severe infection on older trees may cause growth reduction but not mortality. Damage from this disease is generally light.

REFERENCES: Funk, A. 1972. Sirococcus tip-blight of western hemlock in British Columbia and Alaska. Plant Disease Reporter 56: 645-647.

Shaw, C.G.; Laurent, T.H.; Israelson, S. 1981. Development of Sirococcus tip blight following thinning in western hemlock regeneration. U.S.D.A. Forest Service. Pacific Northwest Forest and Range Experiment Station Research Note PNW-387. 6p.

Figure 148.
Branch dieback due to SIROCOCCUS TIP BLIGHT. Note shepherd's crook at tip.

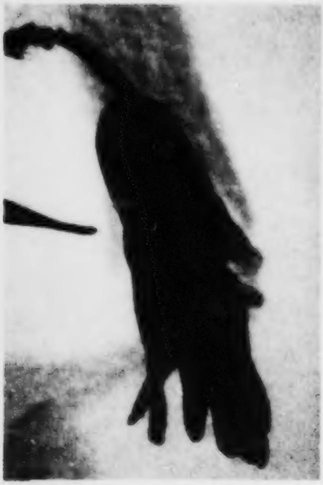


Figure 149.
Shepherd's crook produced by SIROCOCCUS TIP BLIGHT. Note small black fruiting bodies.

SPRUCE NEEDLE CAST *Lirula macrospora* (Hartig) Darker

DISTRIBUTION: Throughout the range of spruce.

TREE SPECIES ATTACKED: All native spruce.

SIGNS AND SYMPTOMS: This pathogen has a two-year life cycle. Infected needles become straw or brown colored, and die. Killed needles remain on twigs longer than naturally senescent needles. Elongate black fruiting bodies are found on dead needles. Spruce needle cast becomes infectious to spruce every second year; therefore, tree foliage may have every second year's growth affected. Infections are more common in the lower crown.

DAMAGE: Successive years of severe infection may cause growth reduction; however, this is uncommon. Mortality seldom occurs.

REFERENCES: Unger, L.S. 1972. Common needle diseases of spruce in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet No. 39. 7p.

WESTERN PINE-ASTER RUST *Coleosporium asterum* (Diet.) Syd.

DISTRIBUTION: Throughout the host range.

TREE SPECIES ATTACKED: Lodgepole pine.

SIGNS AND SYMPTOMS: Small white blisters filled with orange spores develop from discolored patches on either side of the needles, in late spring. Alternate hosts are species of aster.

DAMAGE: Heavily infected older needles are cast. This disease can cause growth reduction in younger trees. In most cases, little or no damage will result from a light to moderate infection.

REFERENCES: Nicholls, T.H.; Patton, E.P. 1976. How to identify and control pine needle rust disease. U.S.D.A. Forest Service. North Central Forest Experiment Station Miscellaneous Report 3.7p.

Figure 150.
Black elongated fruiting bodies of SPRUCE NEEDLE CAST. Killed needles are retained.

Figure 151.
SPRUCE NEEDLE CAST infection of previous year's growth.

Figure 152.
Blisters of WESTERN PINE-ASTER RUST develop on both sides of the needles.

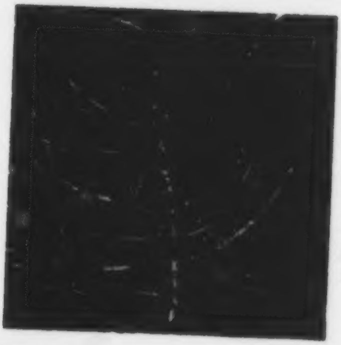


Figure 153.
Needle discoloration produced by WESTERN PINE-ASTER RUST infection of older needles. Note spore-bearing white blisters.

ROOT DISEASES

Root diseases, which affect trees of any age or species, are caused by wood decay or wood staining fungi. With the entry of these organisms into host roots, the root system is gradually killed up to and including the lower bole. As a consequence, tree growth and volume are reduced due to decreased water and nutrient uptake. Eventual mortality is a common occurrence as a result of blowdown or girdling of the root collar. Single species plantations of juvenile trees are particularly susceptible to extensive mortality. Older trees may survive but chronic infection reduces potential volume significantly.

Root diseases primarily spread by root-to-root contact. Rhizomorphs, insects or spores play a minor role in disease spread, according to species. Injury to the roots or root collar may encourage entry of these fungi. However, healthy roots can be invaded when they come in contact with infected wood or roots underground. Infective material can pose a long-term threat to newly established trees, as is the case with Armillaria root disease, laminated root rot, tomentosus root rot and annosus root disease. Black stain root disease does not survive long after death of the host; however, this disease is relatively fast-spreading and potentially very destructive. Insect vectors (black stain root disease) or spore dissemination (annosus root disease) may reduce disease predictability to some extent. Most root disease control measures consist of planting resistant species, establishing mixed stands or de-stumping; pesticides have not been practical or particularly effective to date.

Most root diseases cause similar crown symptoms. These symptoms include chlorosis, reduced terminal growth, crown thinning, and distress cone crop. Affected trees may exist as scattered individuals throughout a stand or may be clumped in noticeable patches called infection centres. A typical infection centre consists of standing infected trees (with or without crown symptoms), standing dead trees, infected stumps and windthrown trees lying in a random crisscross pattern. However, accurate identification is based upon host-specific decay patterns, mycelia or staining in the wood. Therefore, examination of the roots and root collar is always necessary to positively identify root diseases. Fruiting bodies may also be useful for diagnosis if they are present. Fruiting bodies of root disease fungi are usually resupinate or bracket-like on the host, or mushroom-like on the ground around the host. Photographs and descriptions of the more common and economically important root diseases follow.

ANNOSUS ROOT DISEASE *Heterobasidion annosum* (Fr.) Bref.
Previously *Fomes annosus* (Fr.) Cke.

DISTRIBUTION: Throughout the range of western hemlock.

TREE SPECIES ATTACKED: Western hemlock is the principal host. True firs, Douglas-fir, Sitka spruce, western red cedar and yellow cedar are also susceptible.

SIGNS AND SYMPTOMS: Infected trees younger than 15 years may exhibit crown symptoms typical of root diseases, including reduced leader and branch growth, chlorotic foliage and a distress cone crop. In older trees, the fungus causes butt rot, and external symptoms are usually not present. Trees with extensive decay in structural roots are subject to mortality and/or windthrow; this is often the only indicator that this disease is present in a stand. Cream-colored pustules are usually evident on the surface of infected roots.

Fruiting bodies are perennial, woody to leathery, and vary in form from resupinate to bracket-like. The upper surface is dark brown to black, and uneven. The lower surface is white-to cream-colored with small irregular pores. Fruiting bodies are usually found within 30 cm of the soil surface. They are usually produced on upturned roots, root crotches of old stumps, or the lower side of windthrown stems. Incipient decay consists of yellow-brown to red-brown stain in the heartwood. Advanced decay becomes pitted; infected wood is finally reduced to a white, stringy or spongy mass containing black flecks running parallel to the grain. Decay may extend as high as 15 m up the stem.

DAMAGE: Annosus root disease can be very damaging, especially in western hemlock stands. Volume losses are most significant in the form of heart rot. Infections result in growth reduction and mortality. This disease can colonize wounds; thus, stands damaged by previous logging or other activity may have a particularly high incidence of this pathogen.

REFERENCES: Morrison, D.J. 1979. Annosus root rot in Douglas-fir and western hemlock in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 15. 8p.

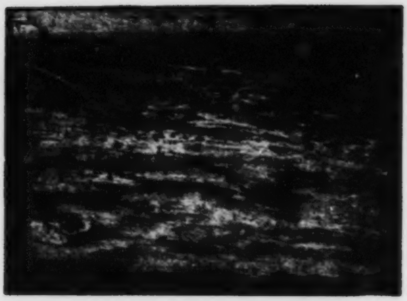


Figure 154. Advanced decay symptoms of ANNOSUS ROOT DISEASE. Black flecks and stringy appearance are distinguishing features.

Figure 155. Resupinate conk of ANNOSUS ROOT DISEASE. Fruiting bodies of this disease exhibit small irregular pores.

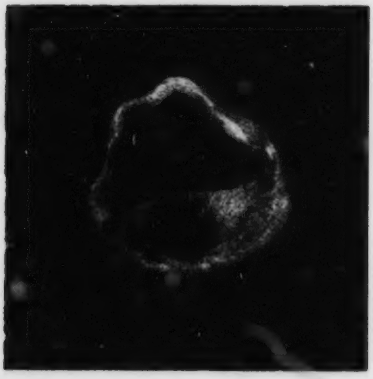


Figure 156. Butt rot caused by ANNOSUS ROOT DISEASE. Note color of incipient decay.

ARMILLARIA ROOT DISEASE *Armillaria ostoyae* (Romagn.) Herink

Previously *Armillaria mellea* (Fr.) Kumm.

DISTRIBUTION: Throughout the province south of 57° latitude.

TREE SPECIES ATTACKED: All native conifer species are susceptible to *A. ostoyae*. Other *Armillaria* species attack deciduous trees in British Columbia.

SIGNS AND SYMPTOMS: This disease may be restricted to scattered individual trees, or may produce extensive infection centres. Infected trees display crown symptoms which include reduced leader and branch growth, thin chlorotic foliage, and distress cone crops. Large quantities of resin are exuded around the lower bole and root collar. Removal of bark from areas of resinosis will expose white mycelial fans between the bark and wood. Mushrooms (fruiting bodies) appear in clumps around the root collar of dead and diseased trees in fall, usually after the first heavy rains. Young mushrooms are cream to brown, with white to brown scales on their stems and caps. There is a conspicuous ring on the stem. Black rhizomorphs, 1-2 mm in diameter, may be found on the surface of roots, or in the soil adjacent to an infected tree or stump.

DAMAGE: This disease causes extensive growth reduction and mortality in the interior of the province, and significant losses on the Coast. In coastal forests, mortality caused by Armillaria root disease begins when trees are about five years old. Maximum mortality occurs in 10-15 year-old trees and is usually rare in trees older than 25 years. On the Coast, groups of one to five trees are killed over a number of years, and incidence rarely exceeds 2-3% of a stand. In interior forests, mortality may begin when trees are 5-10 years old and will continue throughout the rotation. Thus, scattered mortality can amount to 30% of a stand. Partial harvest and disturbances often exacerbate this disease.

REFERENCES: Morrison, D.J. 1981. Armillaria root disease: a guide to disease diagnosis, development and management in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Information Report BC-X-203. 11p.

Figure 157.
Mycelial fans of ARMILLARIA ROOT DISEASE develop between bark and outer wood.

Figure 158.
Resinosis caused by ARMILLARIA ROOT DISEASE. This symptom is common around lower bole.

Figure 159.
Typical crown symptoms of an immature tree infected with ARMILLARIA ROOT DISEASE.

Figure 160.
Mushrooms at base of tree infected with ARMILLARIA ROOT DISEASE.

BLACK STAIN ROOT DISEASE *Leptographium wageneri* (W.B. Kendrick) M. J. Wingfield
Previously *Verticicladiella wageneri* Kendrick (*Ceratocystis wageneri* Goheen and Cobb)

DISTRIBUTION: Southern Interior and coastal British Columbia.

TREE SPECIES ATTACKED: Douglas-fir and lodgepole pine in the Interior; Douglas-fir and western hemlock on the Coast. Other conifers may be attacked.

SIGNS AND SYMPTOMS: Crown symptoms are similar to those of other root diseases. However, this disease may spread more rapidly than the resultant crown symptoms would indicate. A black to brownish purple stain is revealed if the sapwood is cut open. This stain usually follows the annual rings and is present in the lower bole and roots. In contrast, other sapwood stains are typically wedge-shaped and usually bluish in color. Atropellis canker produces a similar black stain, on two- or three-needled pines, but can be distinguished from black stain root disease since discoloration originates from a stem canker. In contrast to other root diseases, wood infected with black stain root disease is not decayed.

Black stain root disease may occur as an infection centre or as infected single trees. It may spread via root contact or by insect vectors. Because this pathogen can be insect-vectored, stressed trees which attract insects may develop black stain as a secondary infection. For this reason, trees should be examined for other diseases or stress factors before black stain root disease is diagnosed. Armillaria root disease is commonly associated with this pathogen. Most root diseases cause death by root decay; however, black stain is a vascular wilt, where death results from plugging of conductive tissue by fungal hyphae. Black stain is relatively short-lived once its host is dead.

DAMAGE: This disease has caused mortality in Douglas-fir up to 60 years old and in pine up to 100 years old. Disease centres of up to 30 trees have been reported in Douglas-fir stands. In interior pine stands, infections of greater than 50% have occurred over areas up to 350 ha.

REFERENCES: Hunt, R.S.; Morrison, D.J. 1979. Black stain root disease in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Forest Pest Leaflet 67. 4p.

Smith, R.S.; Graham, D. 1975. Black stain root disease of conifers. U.S.D.A. Forest Service. Forest Pest Leaflet 145. 4p.

Figure 161.
Sapwood infected with BLACK STAIN ROOT DISEASE. Blackish stain follows the annual rings.

Figure 162.
Crown symptoms of lodgepole pine during advanced stage of BLACK STAIN ROOT DISEASE.

Figure 163.
Thin chlorotic crowns of Douglas-fir infected with BLACK STAIN ROOT DISEASE.

LAMINATED ROOT ROT *Phellinus weirii* (Murr.) Gilbn.

Previously *Poria weirii* Murr.

DISTRIBUTION: Southern half of the province.

TREE SPECIES ATTACKED: Primarily Douglas-fir. Other conifers vary in susceptibility.

SIGNS AND SYMPTOMS: Laminated root rot occurs in pockets. Infection progresses so that standing dead or toppled trees result. The roots of toppled trees are without the root mat that is typical of uninfected windthrown trees. The earliest symptoms are usually visible in the crown. These symptoms include reduced terminal growth, thin chlorotic foliage, and a distress cone crop. Positive identification requires removal of soil around roots to expose the pale white to mauve mycelium on the outer bark. A brown crusty mycelium may also be present where the fungus is exposed to air. Decayed wood separates into layers along the annual rings. Decayed wood has small canoe-shaped pits where reddish brown whisker-like structures, called setal hyphae, are often present. A reddish brown stain is sometimes associated with this decay. Decay does not extend far up the bole. On western red cedar, laminated root rot is limited to a heart rot, and crown symptoms are not displayed.

DAMAGE: Laminated root rot is one of the most damaging diseases in the province. Losses can reach 50% of a stand. Almost all stands with a component of Douglas-fir are infected to some degree. Infected and dead trees are difficult to salvage because infection centres are distributed throughout a stand. Spread is always by root-to-root contact. This pathogen can live for years in dead material left in the soil after logging, and can spread to regenerated stock when their roots contact infected material.

REFERENCES: Nelson, E.E.; Martin, N.E.; Williams, R.E. 1981. Laminated root rot of western conifers. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 159. 6p.

Wallis, G.W. 1976. *Phellinus* (*Poria*) *weirii* root rot detection and management proposals in Douglas-fir stands. Canadian Forestry Service, Pacific Forest Research Centre. Forestry Technical Report 12. 14p.

Figure 164.
Thin, chlorotic crown of immature Douglas-fir infected with LAMINATED ROOT ROT (right). Compare with healthy crown (left).

Figure 165. LAMINATED ROOT ROT infection centre. Note crisscross pattern of windthrow and absence of upturned root mats.

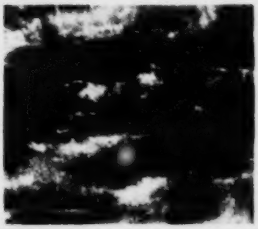


Figure 166.
Setal hyphae are characteristic of advanced LAMINATED ROOT ROT decay (magnified).

Figure 167.
Crusty mycelia of LAMINATED ROOT ROT on surface of bark. Color varies from white to mauve or brown.

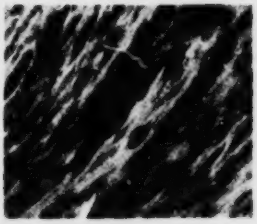


Figure 168. Canoe-shaped pits of LAMINATED ROOT ROT.

RHIZINA ROOT DISEASE *Rhizina undulata* Fr.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: Seedlings of all native conifer species are susceptible.

SIGNS AND SYMPTOMS: Rhizina root disease generally occurs during the first year after broadcast burning. The foliage of infected seedlings becomes discolored, and trees are killed. The symptoms are similar to those produced by drought or other root diseases. Tan-colored strands, 1-2 mm in diameter, are usually interwoven with the root systems of infected seedlings. Fruiting structures are very distinct, and grow within 30 cm of infected seedlings . They are from 2.5-25 cm in diameter, and are chestnut to dark brown. Many brain-like lobes and fissures are present on these fruiting bodies.

DAMAGE: This pathogen may occur in Douglas-fir plantations that were slash-burned prior to planting. Seedling mortality may reach 50% on infected sites, although this situation is rare.

REFERENCES: Ginns, J.H. 1973. Rhizina root rot: severity and distribution in British Columbia. Canadian Journal of Forest Research 4: 143-146.

Thies, W.G.; Kenelm, W.R.; Weir, L.C. 1977. Distribution and damage appraisal of Rhizina undulata in western Oregon and Washington. Plant Disease Reporter 61: 859-862.

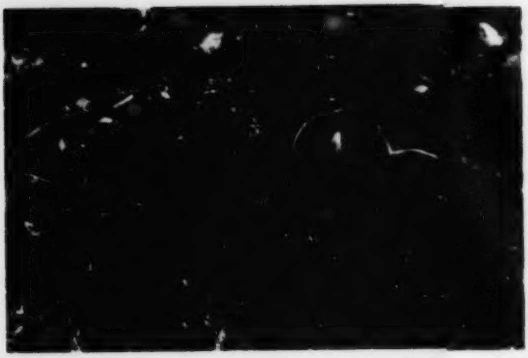


Figure 169.
Seedling killed by RHIZINA ROOT DISEASE. Note surrounding lobe-like fruiting structures.

Figure 170.
Dying seedling infected with RHIZINA ROOT DISEASE. Old fruiting structures are darker in color.

TOMENTOSUS ROOT ROT *Inonotus tomentosus* (Fr.) Gilbn.
Previously *Polyporus tomentosus* Fr.

DISTRIBUTION: Throughout the province following the host range but particularly in spruce stands of the northern Interior.

TREE SPECIES ATTACKED: Spruce species and lodgepole pine are especially vulnerable. Most other pine species, Douglas-fir, all true fir species, western hemlock, western red cedar and western larch can also be attacked.

SIGNS AND SYMPTOMS: Young trees with advanced tomentosus root rot exhibit thin chlorotic crowns and reduced leader growth. A thin white mycelial layer is present under the bark of infected roots or root collar. A slight amount of resinosis is sometimes seen on the lower bole and root collar. Incipient decay consists of a red-brown staining of the heartwood. Advanced decay is characterized by relatively large honeycomb-like pits in infected roots and butts. White areas of elongated spindle-shaped pits are usually intermingled with areas of red-brown, less extensively decayed wood. Leathery conks are produced in fall on the lower stem or on the ground around infected trees. Fruiting bodies growing on the ground are oval and stalked and have a hairy texture with a yellow-brown, rust-brown, or dark brown upper surface. The lower surface has pores and is yellow to greyish brown. Fruiting bodies that form on the lower stem are similar in color but are bracket-like in shape. Older infected trees may have no obvious symptoms of infection.

DAMAGE: Infected trees exhibit growth reduction and mortality, depending on age. Trees may eventually be killed; younger trees are killed rapidly while mortality in older trees occurs after many years of infection. Trees over 60 years of age do not usually succumb to this disease. At least 15 to 20 years elapse between initial infection and death. Trees with extensive root decay are vulnerable to windthrow and often topple in a crisscross manner. Since this pathogen spreads mainly by root contact, stand openings often appear by 35 years and increase in size over a rotation. The harvestable volume is often particularly reduced in spruce species because tomentosus decay can extend for several metres up the stem.

REFERENCES: Hinds, T.E. 1977. Heart rots of Engelmann spruce and subalpine fir in the Central Rocky Mountains. U.S.D.A. Forest Service. Forest Insect and Disease Leaflet 150. 8p.

Whitney, R.D. 1977. *Polyporus tomentosus* root rot of conifers. Canadian Forestry Service, Great Lakes Forest Research Centre. Forestry Technical Report 18. 11p.

Figure 171.
Young spruce tree infected with TOMENTOSUS ROOT ROT. Note distress cone crop and reduced terminal growth.

Figure 172.
Thin crowns of older spruce infected with TOMENTOSUS ROOT ROT.

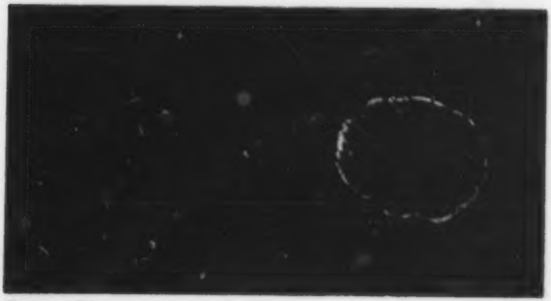


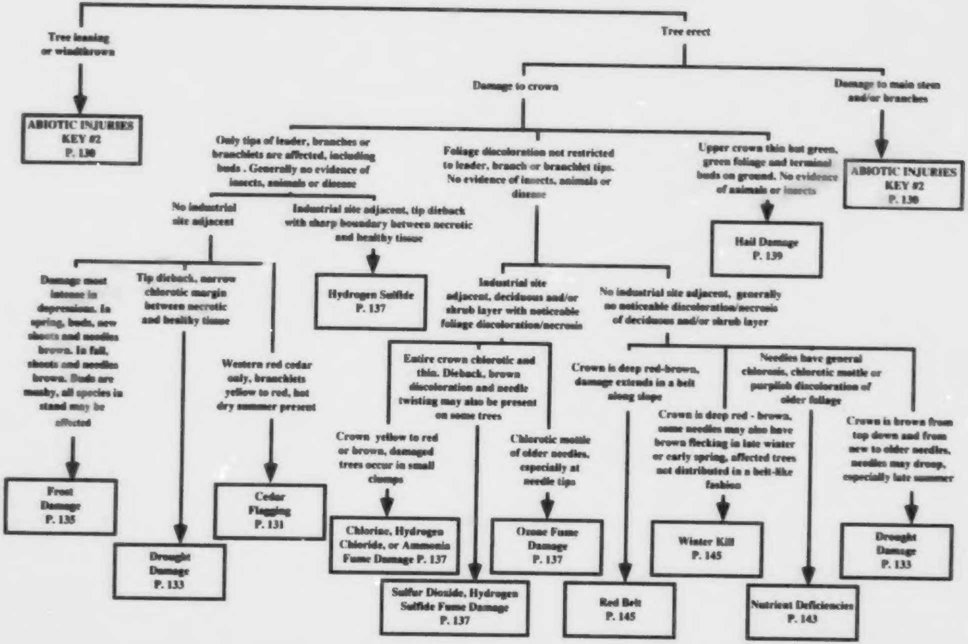
Figure 173.
Fruiting bodies of TOMENTOSUS ROOT ROT.

INTRODUCTION TO ABIOTIC INJURIES

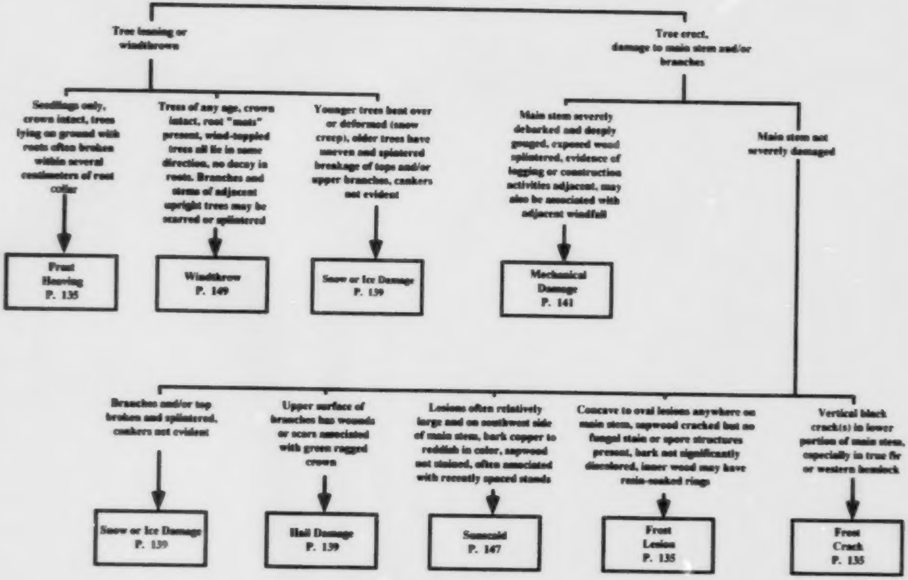
Disorders not caused by insects, fungi, animals or other organisms and that are non-infectious are termed abiotic. The abiotic factors which are responsible for such disorders are mainly those of climate but can also be nutritional or man-made. All tree species throughout the province can be affected by abiotic factors of one type or another at any time. Local topography can favor certain conditions such as frost damage. Excessive site disturbance, increases in site exposure due to removal of the protective overstory by harvesting or fire, or proximity to sources of air pollution at scattered locations throughout British Columbia tend to favor the occurrence of abiotic injuries such as nutrient deficiencies, sunscald, ice/snow/hail damage and fume damage. Decreased wood quality and volume may result. In addition, trees stressed by abiotic injuries are often predisposed to disease and insect attack.

Symptoms caused by abiotic factors are usually very similar to those caused by other agents. Generally, non-infectious disorders are uniformly distributed whereas symptoms of infectious diseases are usually more randomly distributed either on the tree or within a stand. Attacks by animals, sucking insects and woody tissue feeders are also random. Widespread insect defoliation is often uniform, but the evidence of insect attack is always present. As a rule, always check affected areas for evidence such as cankers, fruiting bodies, specific root rot decay characteristics, insects, webbing, girdling, animal tracks, etc., before deciding that abiotic injuries are present. In addition, consider local climate records, topography, location of adjacent industrial sites and roads, and evidence of excessive site disturbance when determining which abiotic factor has caused the damage. Following are photographs and descriptions of the important abiotic injuries affecting British Columbia's forests.

Abiotic Injuries Key #1 - Injuries to Crown/Foliage or Tips


Tree leaning or windthrown
ABIOTIC INJURIES KEY #2 P. 130
Tree erect
Damage to crown
Damage to main stem and/or branches
ABIOTIC INJURIES KEY #2 P. 130
Only tips of leader, branches or branchlets are affected, including buds . Generally no evidence of insects, animals or disease
Foliage discoloration not restricted to leader, branch or branchlet tips. No evidence of insects, animals or disease
Upper crown thin but green, green foliage and terminal buds on ground. No evidence of animals or insects
Hail Damage P. 139
No industrial site adjacent
Industrial site adjacent, tip dieback with sharp boundary between necrotic and healthy tissue
Hydrogen Sulfide P. 137
Damage most intense in depressions. In spring, buds, new shoots and needles brown. In fall, shoots and needles brown. Buds are mushy, all species in stand may be affected
Frost Damage P. 135
Tip dieback, narrow chlorotic margin between necrotic and healthy tissue
Drought Damage P. 133
Western red cedar only, branchlets yellow to red, hot dry summer present
Cedar Flagging P. 131
Industrial site adjacent, deciduous and/or shrub layer with noticeable foliage discoloration/necrosis
Entire crown chlorotic and thin. Dieback, brown discoloration and needle twisting may also be present on some trees
Crown yellow to red or brown, damaged trees occur in small clumps
Chlorine, Hydrogen Chloride, or Ammonia Fume Damage P. 137
Sulfur Dioxide, Hydrogen Sulfide Fume Damage P. 137
Chlorotic mottle of older needles, especially at needle tips
Ozone Fume Damage P. 137
No industrial site adjacent, generally no noticeable discoloration/necrosis of deciduous and/or shrub layer
Crown is deep red-brown, damage extends in a belt along slope
Red Belt P. 145
Crown is deep red - brown, some needles may also have brown flecking in late winter or early spring, affected trees not distributed in a belt-like fashion
Winter Kill P. 145
Needles have general chlorosis, chlorotic mottle or purplish discoloration of older foliage
Nutrient Deficiencies P. 143
Crown is brown from top down and from new to older needles, needles may droop, especially late summer
Drought Damage P. 133

Abiotic Injuries Key #2 - Injuries to Main Stem/Branches or Whole Tree


Tree leaning or windthrown
Tree erect, damage to main stem and/or branches
Seedlings only, crown intact, trees lying on ground with roots often broken within several centimeters of root collar
Frost Heaving P. 135
Trees of any age, crown intact, root "mats" present, wind-topped trees all lie in same direction, no decay in roots. Branches and stems of adjacent upright trees may be scarred or splintered
Windthrow P. 149
Younger trees bent over or deformed (snow creep), older trees have uneven and splintered breakage of tops and/or upper branches, cankers not evident
Snow or Ice Damage P. 139
Main stem severely debarked and deeply gouged, exposed wood splintered, evidence of logging or construction activities adjacent, may also be associated with adjacent windfall
Mechanical Damage P. 141
Main stem not severely damaged
Branches and/or top broken and splintered, cankers not evident
Snow or Ice Damage P. 139
Upper surface of branches has wounds or scars associated with green ragged crown
Hail Damage P. 139
Lesions often relatively large and on southwest side of main stem, bark copper to reddish in color, sapwood not stained, often associated with recently spaced stands
Sunscald P. 147
Concave to oval lesions anywhere on main stem, sapwood cracked but no fungal stain or spore structures present, bark not significantly discolored, inner wood may have resin-soaked rings
Frost Lesion P. 135
Vertical black crack(s) in lower portion of main stem, especially in true fir or western hemlock
Frost Crack P. 135

CEDAR FLAGGING

DISTRIBUTION: Throughout the range of western red cedar.

TREE SPECIES AFFECTED: Western red cedar.

SIGNS AND SYMPTOMS: Isolated branchlets have yellow to red, dying or dead foliage. Cedar flagging is not a disease although these symptoms bear superficial resemblance to cedar leaf blight when the latter occurs in the fall. However, small black cavities will not be found in the upper surface of leaves exhibiting cedar flagging. Flagging is a normal condition of western red cedar and is associated with hot dry summer weather.

DAMAGE: Entire branchlets die but cedar flagging does not have a detrimental effect on tree growth.

REFERENCES: Foster, R.E.; Wallis, G.W. 1974. Common tree diseases of British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Canadian Forestry Service Publication 1245. 81p.

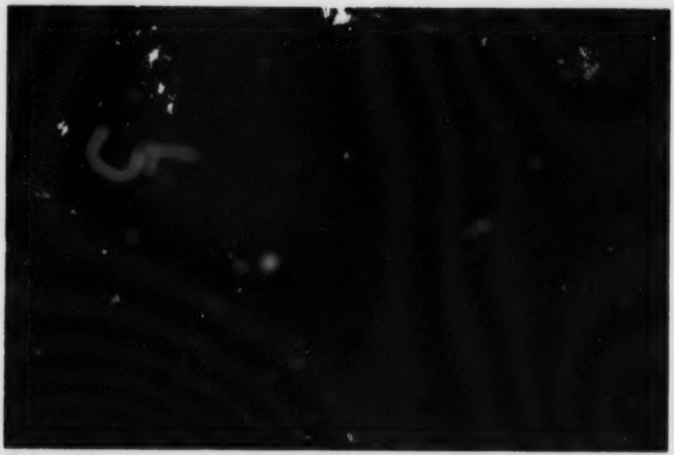


Figure 174.
Dead foliage due to CEDAR FLAGGING on branchlets of western red cedar.

DROUGHT

DISTRIBUTION: Throughout the province in areas experiencing unusually low rainfall, especially on sites with dry aspects and shallow, well drained soils or areas where excessive soil disturbance has occurred.

TREE SPECIES AFFECTED: All conifer species are susceptible, especially seedlings or young saplings. Species or varieties adapted to dry sites are more tolerant than those adapted to moist sites.

SIGNS AND SYMPTOMS: Drought symptoms are most apparent in late summer to early fall and can occur over extensive areas. Younger trees become affected earlier than older trees since the former have a smaller root system. Seedlings show wilting, yellowing, and necrosis of the foliage. Older trees exhibit symptoms from the tip down and from the outside inward. Affected foliage eventually discolors brown in all species except larch. On larch, foliage turns yellow, droops or shrivels around the stem or branches, and falls off abnormally early. With well-advanced drought conditions, foliage discoloration and needle death become more pronounced and tip dieback may be seen. On western white pine, drought-related stem cracks are sometimes found.

DAMAGE: Drought can cause extensive mortality for four or five years after planting. Mortality of older, larger trees is usually not widespread. Instead, damage results in growth reduction and defoliation. However, if drought occurs over several successive years, large trees of intolerant species may die.

REFERENCES: Leaphart, C.D. 1959. Drought damage to western white pine and associated tree species. Plant Disease Reporter 43: 809-813.

McMinn, R.G.; Funk, A. 1970. Unusual drought symptoms in Douglas-fir. Canadian Journal of Botany 48: 2123-2127.

Figure 175.
Foliage discoloration and necrosis caused by DROUGHT.

Figure 176.
Mortality in a young stand due to prolonged DROUGHT. Immature trees are generally more susceptible to damage.

Figure 177.
DROUGHT symptoms move from crown top down and from branch tips inward.

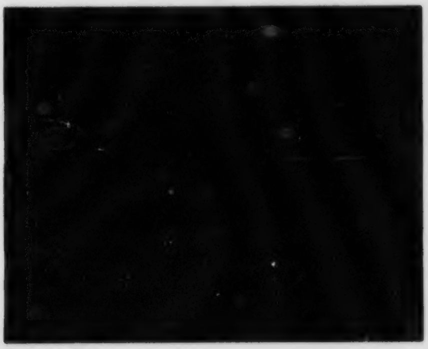


Figure 178.
Detail of DROUGHT stress symptoms on needles.

FROST INJURY

DISTRIBUTION: Throughout the province particularly in areas of poor air drainage (frost pockets) or cold wet soils.

TREE SPECIES AFFECTED: All native and non-native conifer species are susceptible. Interior varieties are more tolerant than coastal varieties of the same species.

SIGNS AND SYMPTOMS: Frost injury results from unusually cold temperatures occurring in late spring or early fall. Frost damage symptoms include one or more of the following: bud or shoot death, frost lesions, internal radial shake, frost cracks, or frost heaving. Late spring frost affects buds just breaking dormancy and succulent new growth. Injury is visible within two days of frost incidence when foliage becomes limp and fades to yellow. After approximately one week, killed buds turn dark brown and soft. Affected foliage of the branch tips becomes red-brown and drooped. These symptoms are often most pronounced in the upper crown of smaller trees on the emerging succulent foliage. Repeated frost injury resembles damage caused by animal browsing. Therefore, investigations for signs of animal activities should be conducted.

Frost lesions are rough, callused patches on the main stem created by frost-killed cambium. Necrotic bark eventually sloughs off to expose the sapwood. Raised lateral woody folds, called frost ribs, surround older cankers. This type of injury generally occurs on young to pole-sized trees. Subsequent freezing of these lesions can cause internal radial shake, seen as brownish, resin-soaked rings of disrupted wood. Frost cracks are usually seen in older trees, especially in true fir species. This type of damage is characterized by long, dark vertical cracks in the main stem. Frost heaving is almost exclusively restricted to first-year seedlings in cold, poorly drained soils. Affected seedlings are ejected from the soil and their roots are generally broken within several centimeters of the root collar.

DAMAGE: Frost damage is rarely restricted to a single species in mixed stands. Late spring frosts are usually more injurious than early fall frosts. Reduced lateral and leader growth or tip dieback is associated with late frosts. Frost heaving is also caused by late frosts, and can result in significant seedling mortality on newly planted sites at higher elevations in the Interior. Internal radial shake can adversely affect growth rates and wood quality. Frost lesions or frost cracks act as entry points for decay fungi or can lead to stem breakage.

REFERENCES: Heidmann, L.J. 1976. Frost heaving of tree seedlings: a literature review of causes and possible control. U.S.D.A. Forest Service. General Technical Report RM-21. 10p.

Zalasky, H. 1985. Frost, ice-nucleating agents, and frost damage. Canadian Forestry Service, Northern Forest Research Centre. Forest Management Note 30. 2p.

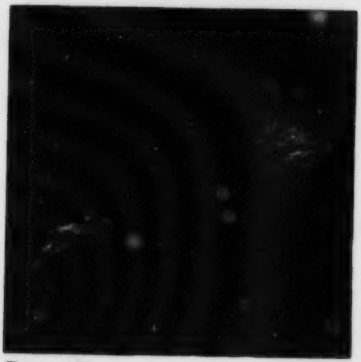


Figure 179.
Soft, brown buds killed by late spring FROST.

Figure 180.
Wilted necrotic needles resulting from late FROST damage to recently flushed foliage.

Figure 182.
FROST-injured tips initially turn yellow. Older damage is dark brown.

Figure 181.
FROST CRACK extending up main stem.

Figure 183. Seedling mortality caused by FROST HEAVE.

FUME DAMAGE

DISTRIBUTION: May be adjacent to some industrial sites.

TREE SPECIES AFFECTED: All tree species are susceptible. In mixed stands, certain species may have more pronounced symptoms, depending upon the chemical agent.

SIGNS AND SYMPTOMS: Fume damage to trees can occur over fairly extensive areas or can be localized as a clump of affected trees. The proximity of industrial sources such as mills or smelters, the local topography, prevailing winds and possible presence of other causal factors must all be considered when fume damage is suspected. Fume damage can sometimes be verified through chemical analysis of the foliage, but results are not always reliable. Fume damage to conifers should be corroborated with symptoms on the foliage of associated deciduous trees or herbaceous vegetation if possible. Symptoms vary between the most common types of industrial emissions which are hydrogen sulfide, sulfur dioxide, nitrogen oxides, ozone, ammonia, chlorine, hydrogen fluoride or hydrogen chloride gases. In addition, improper use of pesticides can affect non-target trees. Therefore, local records of recent pesticide use should be checked when fume damage is suspected.

Sulfur dioxide and hydrogen sulfide fumes usually affect relatively large areas and cause stunted needle growth, chlorosis and subsequent browning of entire needles or needle tips. Entire crowns become thin and chlorotic with extreme exposure to sulfur dioxide. Some trees may exhibit tip dieback due to hydrogen sulfide damage. Ozone, nitrogen oxides and ammonia emissions also affect larger areas up to a considerable distance from the source. Ozone exposure causes general chlorotic mottling of the older needles, especially at the tips where necrosis can also be present. Nitrogen oxides cause formation of necrotic lesions and tip burn on the older needles in particular. The entire crown will eventually discolor a mottled brown with the continual presence of nitrogen oxides. Exposure to ammonia causes slight red to brown foliage discoloration over broad geographic areas or pronounced yellow to red discoloration of the entire crown close to the source. Younger needles are affected first. Chlorine, hydrogen fluoride and hydrogen chloride affect clumps of trees close to the fume source. At high concentrations, the entire crown discolors yellow to red or brown. Standing dead trees may be present. Lower concentrations cause brown tip dieback of the needles, with a sharp boundary between healthy and necrotic tissues, and overall discoloration of the entire crown.

DAMAGE: Exposure to sudden high concentrations or to continual chronic levels of industrial emissions causes growth reduction and mortality. Trees stressed by exposure to industrial fumes are also predisposed to attack by insects or disease.

REFERENCES: Malhotra, S.S.; Blauel, R.A. 1980. Diagnosis of air pollutant and natural stress symptoms on forest vegetation in western Canada. Canadian Forestry Service, Northern Forest Research Centre. Information Report NOR X-228. 84p.

Figure 184.
Damage resulting from high concentrations of CHLORINE FUMES. Note pronounced discoloration.

Figure 185.
Necrotic tips resulting from exposure to HYDROGEN SULFIDE or SULFUR DIOXIDE FUMES.

Figure 187.
Chlorotic flecking on needles caused by FUME residues.

Figure 186.
Damage resulting from PESTICIDE use.

ICE/SNOW/HAIL DAMAGE

DISTRIBUTION: Throughout British Columbia wherever the incidence of snow or ice is significant.

TREE SPECIES AFFECTED: All native conifers are susceptible. Douglas-fir is more readily damaged than true fir, pine, or hemlock species. Seedlings and young saplings sustain less damage than older trees.

SIGNS AND SYMPTOMS: Signs of snow damage are usually more apparent in dense stands of young trees since these trap a heavier snow load than thinner stands. Snow damage consists of temporarily or permanently bent main stems, depending upon duration and movement of the snow pack, and branch stripping, stem breakage or uprooting. Symptoms are concentrated in small groups or are seen on scattered individual trees in affected stands. Older trees can suffer top breakage. Windblown ice crystals abrade portions of the main stem above the snow-line. Affected areas of the stem have a smooth appearance. Hail damage symptoms can be seen over a broader area and consist of stripped branches, stem lesions, scars and bruises on the upper surface of branches, or tattered, ragged crowns with missing foliage and buds. Damage symptoms are aligned in one direction. Buds, foliage, and branches litter the ground. Larger seedlings and saplings show more symptoms than smaller trees.

DAMAGE: Heavy snowfall or hail can cause significant mortality in young plantations. Losses occur in patches or as scattered individual trees. Growth is reduced when foliage and buds are removed. In younger trees, deformity results from permanently bent main stems or broken tops due to snow press. Deformity of older trees is caused by top breakage. Hail-related branch or stem scars act as entry points for disease.

REFERENCES: Leaphart, C.D.; Hungerford, R.D.; Johnson, H.E. 1972. Stem deformities in young trees caused by snow-pack and its movement. U.S.D.A. Forest Service. Research Note INT-158. 3p.

Powers, R.F.; Oliver, W.W. 1970. Snow breakage in a pole-sized ponderosa pine plantation: more damage at high stand densities. U.S.D.A. Forest Service. Research Note PSW-218. 3p.

Figure 188.
Leader breakage due to SNOW press.

Figure 189.
HAIL-induced lesions on upper surface of branch.

Figure 190.
Broken and bent stems caused by heavy SNOW pack.

Figure 191.
SNOW-related crown deformity and branch stripping.

MECHANICAL DAMAGE

DISTRIBUTION: Throughout the province. Associated with logging road construction, timber harvesting, and windthrow.

TREE SPECIES AFFECTED: All conifer species are susceptible, but species with thinner bark may suffer greater damage.

SIGNS AND SYMPTOMS: Mechanical damage is frequently caused by logging activities such as falling, yarding or equipment operation during road construction. Juvenile spacing may also cause mechanical damage to crop trees if they are struck by felled trees or nicked by a chainsaw. Trees may be severely debarked and deeply gouged in an irregular manner on one side of the lower bole. Wood damaged by logging or construction equipment is often distinctly splintered in appearance. Stems struck by falling trees are often scarred much higher up. Such trees usually exhibit broken branches and are associated with adjacent windthrown trees.

DAMAGE: Scars caused by logging or construction activity seldom result in direct mortality. Mortality occurs only when the lower stem is completely girdled or broken. However, mechanical damage leaves extensive entry points for woodstaining or decay fungi. Indirect long-term losses can thus be significant.

Figure 192.
MECHANICAL DAMAGE is prevalent along roads and harvesting boundaries.

Figure 193.
Deep gouging and splintered wood typical of MECHANICAL DAMAGE.

NUTRIENT DEFICIENCIES

DISTRIBUTION: Throughout the province, particularly on poor sites or areas where severe disturbance has occurred.

TREE SPECIES AFFECTED: All conifer species are susceptible especially when growing off-site.

SIGNS AND SYMPTOMS: Nutrient deficiencies cause subtle, non-specific symptoms and may thus be difficult to detect. Symptoms such as slight foliage discoloration and reduced growth rate appear gradually. Nitrogen, potassium and phosphorus deficiency are probably most common, although deficiencies in other nutrients have been documented. Generally, foliage gradually turns chlorotic and then bleached when nitrogen, potassium or most other nutrients are not available in adequate amounts. Needles and shoots sometimes become twisted. Boron deficiency has been implicated in swelling and deformation of leaders. Purple discoloration of the older foliage followed by withering indicates phosphorus deficiency. In any case, discoloration can be either very subtle or pronounced, and can be the combined result of deficiencies in more than one nutrient. For this reason, soil and foliage analyses should be performed for an accurate diagnosis. In addition, an overall assessment of the site should be conducted when nutrient deficiencies are to be considered. Suspect nutrient shortages on sites that have been severely burned, scarified, or excessively compacted. Soil compaction is often found on skid trails and landings. Thus, symptomatic trees may be distributed exclusively on these areas. Severe burning or excessive scarification will remove much of the nutrient-rich topsoil from a site. Therefore, symptomatic trees may appear in clumps or as scattered individuals throughout these sites.

DAMAGE: Nutrient deficiencies lead to volume losses due to long-term reduced growth rates. In severe cases, trees eventually die. Trees are stressed when nutrients are in short supply; thus, they are predisposed to insect attack or disease.

REFERENCES: Carter, R.E.; Klinka, K. 1986. Symptoms and causes of distorted growth in immature forest stands in coastal British Columbia. B.C. Ministry of Forests. Land Management Report 39.

Krause, H.H. 1981. Factorial experiments with nitrogen, phosphorus and potassium fertilizers in spruce and fir stands of New Brunswick: 10-year results. Canadian Forestry Service, Maritime Forest Research Centre. Information Report M-X-123. 12p.

Figure 194.
Chlorotic shoots caused by NUTRIENT DEFICIENCY.

Figure 195.
NUTRIENT DEFICIENCY symptoms occurring on disturbed site.

Figure 196.
Needle chlorosis due to NUTRIENT DEFICIENCY.

RED BELT/WINTER KILL

DISTRIBUTION: Throughout the province, mainly along the middle to upper portions of south to southwest slopes.

TREE SPECIES AFFECTED: All conifer species are susceptible, particularly lodgepole pine.

SIGNS AND SYMPTOMS: Trees are discolored reddish brown over large areas. When viewed from a distance, such areas form bands with distinct upper and lower vertical limits. This pattern is seen along slopes in valleys and mountainous areas. Red belt results when trees in frozen ground are subjected to sudden warm, drying winds and then a rapid drop in temperature. Foliage and exposed buds lose moisture which can not be readily replaced. Consequently, foliage and buds discolor but remain undistorted. Dead buds eventually become soft. Foliage within unopened buds is usually unharmed. Symptoms are often more pronounced in the upper crown and on the sides of trees facing the prevailing wind. These symptoms are also occasionally seen on flat, low elevation terrain when the above-mentioned conditions occur, but the damage is not belt-like in distribution. This phenomenon is termed winter kill.

DAMAGE: Foliage and buds are killed. Trees often recover from extensive defoliation but mortality may result if all buds are destroyed. Affected trees have a reduction in growth rate. The extent of damage may vary depending on seed source. Trees weakened by red belt or winter kill are more susceptible to insect attack or disease.

REFERENCES: Bella, I.E.; Navratil, S. 1987. Growth losses from winter drying (red belt damage) in lodgepole pine stands on the east slopes of the Rockies in Alberta. Canadian Journal of Forest Research 17: 1289-1292.

Robins, J.K.; Susut, J.P. 1974. Red belt in Alberta. Canadian Forestry Service, Northern Forest Research Centre. Information Report NOR-X-99. 6p.

Figure 197.
Typical bands of reddish brown trees caused by RED BELT.

Figure 198.
Leader exhibiting symptoms of WINTER KILL.

Figure 199.
Foliage affected by RED BELT discolors but remains undistorted.

SUNSCALD

DISTRIBUTION: Throughout the province wherever temperatures reach levels high enough to kill the cambium in young trees.

TREE SPECIES AFFECTED: Young trees of any species are susceptible. Douglas-fir may be particularly vulnerable.

SIGNS AND SYMPTOMS: The southwest side of the main stem is generally most affected. The outer bark on the stems of recently damaged trees is coppery to bright red. Older damage is a darker red to brown color. This discoloration fades by the end of summer. Necrotic bark shrinks, becomes loose, and sloughs off. Sunscald cankers may vary from small patches to large areas extending almost the entire length of the exposed stem. Injured areas are confined to smooth, unfissured sections of the bark. Damaged trees are commonly seen in summer on droughty sites or in areas where thinning has been carried out, since these conditions predispose trees to the effects of intense direct sunlight. Rapidly growing trees may also be affected. Sunscald incidence is often greater along the open edges of a stand.

DAMAGE: Necrotic areas may allow the entry of decay-causing fungi. However, significant growth losses or mortality are seldom directly attributable to sunscald.

REFERENCES: Foster, R.E.; Wallis, G.W. 1974. Common tree diseases of British Columbia. Canadian Forestry Service, Pacific Forest Research Centre. Canadian Forestry Service Publication 1245. 81p.

Figure 200. Coppery red bark of an immature Douglas-fir affected by SUNSCALD.

Figure 201. SUNSCALD-killed Douglas-fir. Damage may be more frequent along perimeter of dry exposed sites.

Figure 202. Necrotic lesion caused by SUNSCALD.

WINDTHROW

DISTRIBUTION: Throughout the province, especially in areas where wind-funnelling, shallow soils or root disease occur.

TREE SPECIES AFFECTED: All conifer species are susceptible.

SIGNS AND SYMPTOMS: Windthrow is either distributed as large patches of catastrophic windthrow or as small scattered patches down to individual trees. The latter distribution is termed endemic windthrow and is an ongoing process. Catastrophic windthrow is generally associated with severe storms. Windthrown trees, uprooted or broken off at the bole, lie parallel to one another in patches. Affected trees are commonly found in V-shaped or square cornered clearcuts, on steep rocky slopes, in areas of shallow soil, or where disease has extensively weakened main stems or root systems. Trees do not all lie in the same direction when root disease is implicated. In addition, trees unaffected by root disease exhibit an extensive upturned root mat. Trees of all ages are susceptible but taller trees in a stand are usually windthrown first.

DAMAGE: Windthrow invariably results in mortality. Significant losses may result from catastrophic windthrow. Affected trees have broken root systems and/or main stems. Damage is more extensive in dense stands. Standing trees around patches of windthrow are often scarred or suffer crown damage when hit by falling trees.

REFERENCES: Foster, R.E.; Wallis, G.W. 1974. Common tree diseases of British Columbia, Canadian Forestry Service, Pacific Forest Research Centre. Canadian Forestry Service Publication 1245. 81p.

Figure 203. Large area of timber showing effects of catastrophic WINDTHROW.

Figure 204. WINDTHROW occurs as either broken stems or uprooted trees with intact root mats.

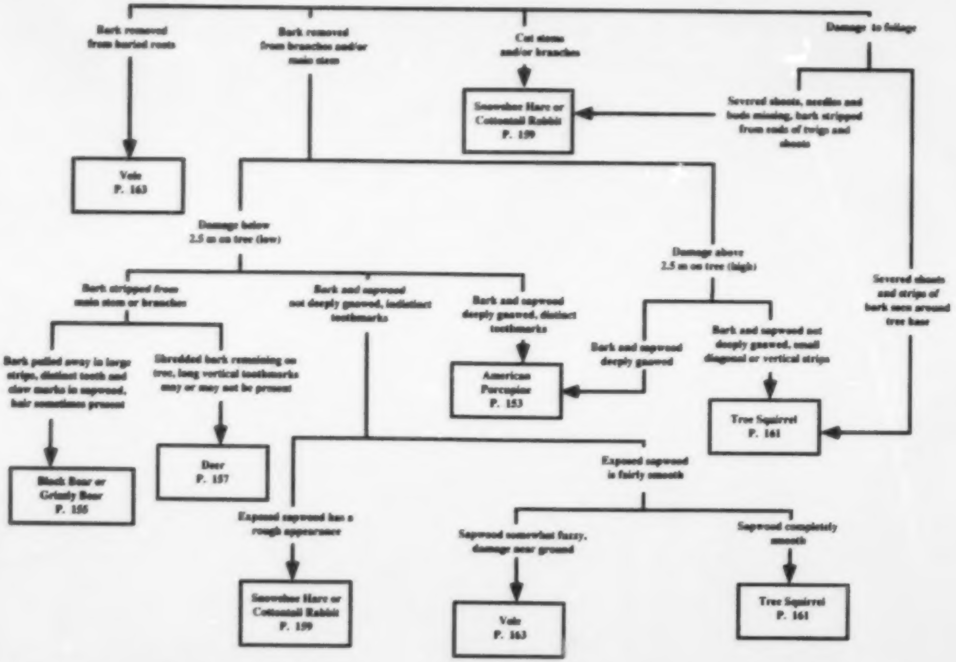
Figure 205. WINDTHROW due to high winds along stand perimeter. Note the parallel formation.

INTRODUCTION TO ANIMAL DAMAGE

A number of wildlife species damage conifers throughout the province. All conifer species are susceptible, particularly at the seedling to sapling stage. Generally, damage is fairly minor and sporadic in occurrence compared to the impact of insects, disease and abiotic injuries on British Columbia's forests. American beaver, mountain beaver, elk, moose, American pika, pocket gopher, sapsuckers, and bushy tailed wood rat are only responsible for sporadic and minor losses. However, significant economic losses due to animal feeding occasionally take place, such as those resulting from porcupine feeding on pole-sized trees, and deer, or snowshoe hare browsing on seedlings. Some species cause more than one type of damage. Depending on the species involved, damage consists of chewed or cut roots, debarking of the main stem or branches, and/or removal of foliage and buds. Reduced growth rate, lost volume, deformity and mortality can result. In addition, wounding allows the entry of disease organisms. Agricultural stock may also cause injury on some sites. Damage from livestock consists of trampled seedlings, browsing, or abrasion of the main stem bark.

Most damage occurs during the spring and summer months. Some damage, such as clipped seedlings, can easily be attributed to animal activity. However, accurate identification of the animal involved is often difficult because damage symptoms are similar between species. Thus, the area around affected trees should be examined for signs of animal activity such as tracks, runways in the grass, burrows, and feces. Control measures consist of baiting, trapping, and placement of browse guards. In addition, habitat manipulation may be helpful in some cases since elk, deer or moose often prefer to feed in open areas such as newly established plantations. Photographs and descriptions of animal species which may damage the forests of British Columbia follow.

Animal Damage Key #1 - American Porcupine, Black/Grizzly Bear, Deer, Hare/Rabbit, Tree Squirrel , Vole


Bark removed from buried roots
Vole P. 163
Bark removed from branches and/or main stem
Cut stems and/or branches
Snowshoe Hare or Cottontail Rabbit P. 159
Damage to foliage
Severed shoots, needles and buds missing, bark stripped from ends of twigs and shoots
Severed shoots and strips of bark seen around tree base
Damage below 2.5 m on tree (low)
Damage above 2.5 m on tree (high)
Bark stripped from main stem or branches
Bark and sapwood not deeply gnawed, indistinct toothmarks
Bark and sapwood deeply gnawed, distinct toothmarks
Bark and sapwood deeply gnawed
Bark and sapwood not deeply gnawed, small diagonal or vertical strips
American Porcupine P. 153
Tree Squirrel P. 161
Bark pulled away in large strips, distinct tooth and claw marks in sapwood, hair sometimes present
Shredded bark remaining on tree, long vertical toothmarks may or may not be present
Black Bear or Grizzly Bear P. 155
Deer P. 157
Exposed sapwood is fairly smooth
Exposed sapwood has a rough appearance
Sapwood somewhat fuzzy, damage near ground
Sapwood completely smooth
Snowshoe Hare or Cottontail Rabbit P. 159
Vole P. 163
Tree Squirrel P. 161

AMERICAN PORCUPINE *Erethizon dorsatum* Allen

DISTRIBUTION: Throughout the province, with the exception of Vancouver Island and the Queen Charlotte Islands.

TREE SPECIES ATTACKED: Sitka spruce, pine and larch species of all ages are particularly susceptible. All other conifer species are affected less frequently.

SIGNS AND SYMPTOMS: Bark is gnawed from trees rather than being stripped. Basal girdling is more common on seedlings and smaller saplings while debarking of the upper stem and major branches occurs on larger saplings to semi-mature trees. Symptoms are generally evenly distributed on the upper bole and throughout the crown of these older trees. The sapwood is always deeply gnawed and prominent horizontal toothmarks approximately 2.5 mm wide can be seen. Small strips of bark may be found around the base of attacked trees. Some branch cutting may also occur. Attacked trees may display characteristic bushy crowns and spike-tops as a result of top girdling. Tracks are not prominent during the summer months but may be seen during winter. Abundant droppings are usually found around recently attacked trees. Droppings are single or linked together in short chains. They are 2.5 cm long, narrow and curved, and have rounded ends.

DAMAGE: Porcupine attack on conifers often causes serious losses in British Columbia. Scattered mortality can occur over fairly extensive areas. Trees die when the lower portion of the stem is girdled. Top kill, deformity, and reduced growth rate result from feeding activities on the upper stem and in the crown.

REFERENCES: Harestad, A.S.; Bunnell, F.L.; Sullivan, T.P.; Andrusiak, L. 1986. Key to injury of conifer trees by wildlife in British Columbia. B.C. Ministry of Forests. Publication WHR - 23. 38p.

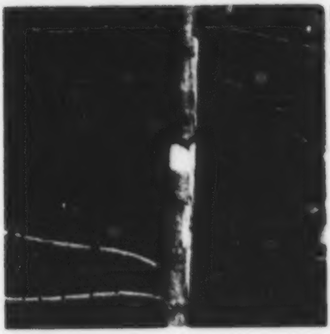


Figure 206.
Stem girdling on larch due to AMERICAN PORCUPINE feeding.

Figure 207.
Teeth marks left in sapwood by AMERICAN PORCUPINE.

Figure 208.
Top kill resulting from upper stem girdling by AMERICAN PORCUPINE.

BLACK BEAR *Ursus americanus* Pallas
GRIZZLY BEAR *Ursus arctos horribilus* Ord.

DISTRIBUTION: Black bears are distributed throughout the province. Grizzly bears usually inhabit more remote areas at higher elevations and are not found on Vancouver Island or the Queen Charlotte Islands.

TREE SPECIES ATTACKED: All conifer species are susceptible.

SIGNS AND SYMPTOMS: Both bear species have similar signs and inflict the same damage. Large sections of the bark are stripped from trees and lie around the tree bases. The exposed sapwood has long vertical grooves left by the canine teeth during feeding. Some debarking may be found in the crown but most feeding is confined to the lower main stem. Resinosis and animal hair is sometimes found in association with damaged areas. Bear droppings are either a circular mass or are large and cylindrical. Tracks are large and claw marks at the end of the five toes are usually very visible. Tracks left by the hind feet are oblong and those left by the fore feet are oval. Claw marks on trees, or logs and stumps that are ripped apart, may also be visible in the surrounding area.

DAMAGE: The incidence of bear damage is generally very scattered. Trees are usually killed due to the destruction of extensive areas of sapwood. More often, trees pole-sized or larger are attacked, although saplings may also be attacked. In general, bear damage is much less frequent than damage caused by other animals.

REFERENCES: Harestad, A.S.; Bunnell, F.L.; Sullivan, T.P.; Andrusiak, L. 1986. Key to injury of conifer trees by wildlife in British Columbia. B.C. Ministry of Forests. Publication WHR - 23. 38p.

Figure 209
GRIZZLY/BLACK BEAR remove large strips of bark from lower bole and leave vertical grooves in the sapwood

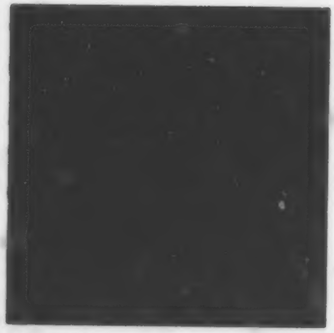


Figure 210
Scattered mortality from GRIZZLY/BLACK BEAR damage

DEER *Odocoileus* spp.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: All conifer species are susceptible, especially western red cedar.

SIGNS AND SYMPTOMS: Terminal and lateral shoots are removed from seedlings and saplings during browsing activities. Browsed ends are squarely cut and have a ragged appearance. Feeding deer sometimes uproot seedlings entirely. Young bark may be peeled from sapling stems leaving vertical toothmarks approximately 4 mm wide in the exposed sapwood. Bark is also stripped from the branches and trunk of saplings during antler polishing. Shredded bark clings to these injured areas. All the preceeding injuries are confined to the lower 1.3 m of the tree. Stunted bushy growth is seen on seedlings and saplings that have been repeatedly browsed. Droppings are usually found in small groups of cylindrical pellets 1.0 to 1.5 cm long. Tracks are sharply pointed and consist of two-parted hoofmarks up to 7.5 cm long. Numerous trails can be seen when the deer population is high in the local area.

DAMAGE: Occasionally, seedlings are killed if pulled from the ground. More commonly, browsing on terminal and lateral shoots causes growth loss and deformation in seedlings and saplings. Repeated browsing results in severe height suppression over extensive portions of affected plantations. Most damage occurs in the spring during bud flush.

REFERENCES: Hartwell, H.D. 1973. Effect of deer browsing on height growth of Douglas-fir trees. Washington State Department of Natural Resources. DNR Note 5. 5p.

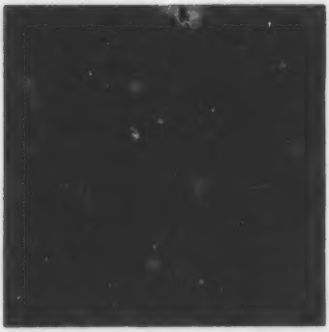


Figure 211.
Seedling browsed by DEER. Note ragged appearance of cut end.

Figure 212.
Stunted, bushy growth of Sitka spruce resulting from repeated DEER browsing.

SNOWSHOE HARE *Lepus americanus* Erxleben
COTTONTAIL RABBIT *Sylvilagus* spp.

DISTRIBUTION: The snowshoe hare is found throughout the province, with the exception of Vancouver Island and the Queen Charlotte Islands. The cottontail rabbit is distributed in the south central portion of the province.

TREE SPECIES ATTACKED: All conifer species are susceptible. Older trees are not affected.

SIGNS AND SYMPTOMS: Snowshoe hare and cottontail rabbit cause similar injuries. However, damage from cottontail rabbit is much less common. Seedlings are cut in an oblique, knife-like manner and the lateral or terminal shoots are removed. Bark is gnawed in small patches near the base of the stem or on the lower branches. The stem is occasionally girdled. Exposed sapwood exhibits a shaggy or ragged appearance with indistinct horizontal or diagonal toothmarks that are approximately 2 mm in width. Injury usually occurs on young seedlings up to 60 cm above ground or snow level and on stems as thick as 6 cm. Droppings are slightly flattened and circular, about 1 cm in diameter and often found in small clusters. Cottontail rabbit droppings are more disk-shaped while those of snowshoe hare are pellet-like. Tracks made by the hind feet of these species are elongate but snowshoe hare leaves longer imprints. Symptoms are often associated with adjacent dense herbaceous or shrub vegetation or slash accumulations.

DAMAGE: Smaller seedlings are highly susceptible to mortality from clipping at the root collar. Larger seedlings suffer deformity, reduced growth rate and occasional mortality. Most damage occurs within several years of planting and follows a very regular 9 to 11 year population cycle.

REFERENCES: Walters, J.; Soos, J. 1961. The relative efficiency of three hare-repellants in protecting Douglas-fir seedlings. Forestry Chronicle 37: 22-28.

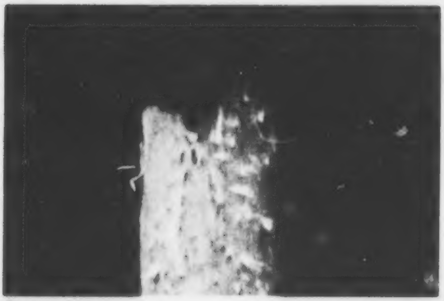


Figure 213.
Ragged, exposed sapwood caused by SNOWSHOE HARE/COTTONTAIL RABBIT feeding.

Figure 214.
Mortality due to stem girdling by SNOWSHOE HARE/COTTONTAIL RABBIT.

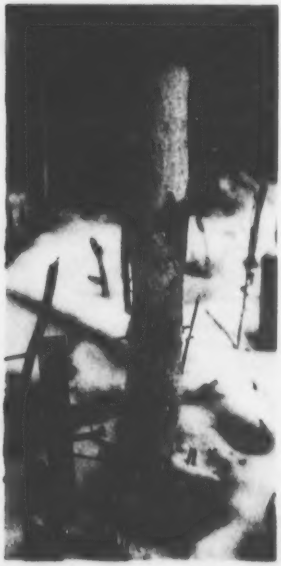


Figure 215.
SNOWSHOE HARE/COTTONTAIL RABBIT often gnaw patches of bark near tree bases.

TREE SQUIRREL *Tamiasciurus* spp.

DISTRIBUTION: Throughout the province.

TREE SPECIES ATTACKED: All conifer species are susceptible but pine species are particularly attacked.

SIGNS AND SYMPTOMS: Saplings to semi-mature trees can exhibit injuries. Tree squirrels cut or peel the lateral and terminal shoots and remove or hollow out the buds. These are often found on the ground around affected trees. Vertical or diagonal strips of gnawed bark up to 1 cm wide occur on the branches and main stem of saplings. Gnawed surfaces are smooth and toothmarks are indistinct. Short strips of bark may be found at the tree base as a result of crown girdling and occasional dead tops may be visible. Freshly cut cones and piles of cone scales on the ground indicate tree squirrel activity. Droppings are elliptical and are 8 mm in length.

DAMAGE: Tree growth is reduced due to feeding on the lateral or terminal buds. Scattered dead tops result from occasional girdling in the crown. Partial basal girdling of saplings can occur over extensive areas in some plantations, leading to reduced growth and scattered mortality. Squirrel populations fluctuate with the size of the cone crop. Thus, damage may be more noticeable during some years than others.

REFERENCES: Harestad, A.S.; Bunnell, F.L.; Sullivan, T.P.; Andrusiak, L. 1986. Key to injury of conifer trees by wildlife in British Columbia. B.C. Ministry of Forests. Publication WHR - 23. 38p.

Figure 216.
Girdling of branches by TREE SQUIRREL. Surface of sapwood is smooth.

Figure 217.
Discolored branch tips damaged during TREE SQUIRREL feeding.

Figure 218.
Damage to lateral shoots from TREE SQUIRREL activity in upper crown.

VOLE *Microtus* spp

DISTRIBUTION: Throughout the province with the exception of the Queen Charlotte Islands.

TREE SPECIES ATTACKED: All conifer species are susceptible.

SIGNS AND SYMPTOMS: Voles, or field mice, clip the terminal and lateral shoots of small seedlings, leaving a rough oblique cut. Larger seedlings and saplings are debarked and often girdled. The bark is gnawed rather than stripped thus giving the exposed sapwood a fuzzy appearance. Toothmarks are indistinct, 1.5 mm wide and 8 mm long, and resemble light scratches. Irregular patches of gnawed bark can also be seen on the roots, root collar, lower stem and occasionally on the lower branches. Small runways can be found in the grass and small piles of clipped vegetation occur along these paths. Small tunnels and mounds of soil are constructed near roots or slash. Vole droppings are cylindrical, have round ends and are about 5 mm long.

DAMAGE: Most damage occurs on younger trees during late summer or winter and can be extensive in some plantations. Winter feeding takes place under the snow. Small seedlings have reduced growth or are killed as a result of clipping. Growth rates of larger seedlings and saplings can also be adversely affected by feeding activities on the roots, root collar, lower stem and lower branches. Girdling of these trees causes scattered mortality. Lemmings occasionally cause similar damage symptoms.

REFERENCES: Anderson, G.G. 1980. Rodent control on agricultural land in British Columbia. B.C. Ministry of Agriculture. Publication 80-6. 15p.

Figure 219.
Plantation damage resulting from extensive VOLE activity.

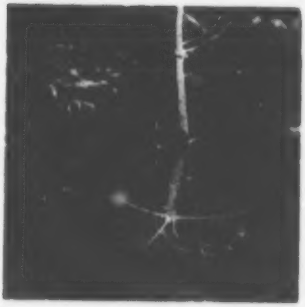


Figure 220.
Sapling completely debarked by VOLES.

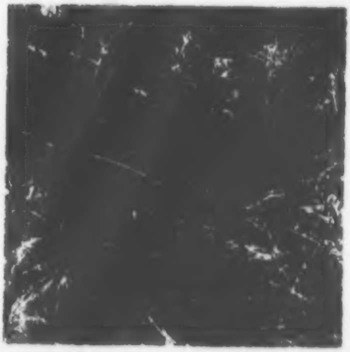


Figure 221.
Mounds of soil from VOLE tunnelling activity adjacent to seedlings.

USING THE HOST-PEST INDEX

Only pests or abiotic factors discussed in this field guide are included. The host-pest index should not be used by itself for pest identification. Instead, the keys, descriptive text, and host-pest index should be employed together. Use the host-pest index to verify the possibility that particular damaging agents could be found on certain areas of the host.

Host common names are listed in alphabetical order in the host-pest index. Each host is then subdivided into the following sections: branch tips or leaders, foliage, main stem or branches, and roots or root collar. Insects, diseases, abiotic injuries and animals are alphabetically listed by common name under the relevant section(s), depending on where the most specific signs and symptoms initially appear. This arrangement facilitates identification since many damaging agents cause additional non-specific symptoms to other portions of the host. For example, most root disease organisms cause a general chlorosis of the crown. However, certain insect species and animal pests also produce this symptom. The species responsible for this chlorosis can only be determined by examining the roots and/or root collar where specific signs and symptoms can be seen. Thus, root diseases are listed under the roots or root collar section of each host in this index, despite affecting the crown.

Woody tissue feeder and animal species are placed under the section on branch tips or leaders. Defoliators, some species of sucking insect, and needle casts, blights and rusts are listed under the foliage section. Certain woody tissue feeders, sucking insects and animal species, as well as broom rusts, dwarf mistletoes, and branch/stem cankers and diebacks are found under the main stem or branches section. Abiotic factors and many animal species often cause direct damage to more than one area of a tree, and are listed accordingly. Page numbers beside each pest direct the reader back to the descriptive text and photographs for tentative confirmation. Suitable specimens should always be collected and shipped for final identification according to the specimen collection and shipment section which follows this host-pest index.

HOST-PEST INDEX

FOR INSECTS, DISEASES, ABIOTIC AND ANIMAL DAMAGE BY AREA OF HOST INITIALLY AFFECTED

HOST	PART OF TREE DAMAGED	PEST	PAGE
Douglas-fir	Branch Tips or Leaders	**Abiotic Injuries**	
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HOST	PART OF TREE DAMAGED	PEST	PAGE
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		Animals	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Insects**	
		Conifer Seedling Weevil (on seedlings)	43
		Diseases	
		Annosus Root Disease (occas.)	115
		Armillaria Root Disease	117
		Black Stain Root Disease	119
		Laminated Root Rot	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163

HOST	**PART OF TREE DAMAGED**	**PEST**	**PAGE**
Larch Western Larch and Eastern Larch (Tamarack)	Branch Tips or Leaders	**Insects**	
		Spruce Budworm (occas.)	23
		Abiotic Injuries	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (occas., on seedlings)	9
		Bud moth	11
		Douglas-fir Tussock Moth	13
		Larch Casebearer	17
		Larch Sawfly	19
		Diseases	
		Larch Needle Blight	101
		Larch Needle Cast	103
		Abiotic Injuries	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145
	Main Stem or Branches	**Diseases**	
		Larch Dwarf Mistletoe	89
		Sydowia Tip Dieback	65
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149

HOST	PART OF TREE DAMAGED	PEST	PAGE
Larch		**Animals**	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Diseases**	
		Armillaria Root Disease	117
		Laminated Root Rot (occas.)	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163
Pines, Five-Needled Western White, Whitebark, or Limber Pine	Branch Tips or Leaders	**Diseases**	
		Sirococcus Tip Blight (on seedlings)	109
		Abiotic Injuries	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (occas., on seedlings)	9
		Pine Needle Sheathminer (occas.)	21
		Diseases	
		Red Band Needle Disease	107

HOST	PART OF TREE DAMAGED	PEST	PAGE
Pines, Five-Needled		**Abiotic Injuries**	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145
	Main Stem or Branches	**Diseases**	
		Larch Dwarf Mistletoe (western white pine, occas.)	89
		Sydowia Tip Dieback	65
		White Pine Blister Rust	75
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Diseases**	
		Armillaria Root Disease	117
		Rhizina Root Disease (on seedlings)	123
		Animals	
		Vole	163
Pines, Two-or Three-Needled Lodgepole or Ponderosa Pine	Branch Tips or Leader	**Insects**	
		Lodgepole Pine Terminal Weevil	45
		Diseases	
		Sirococcus Tip Blight (on seedlings)	109

HOST	PART OF TREE DAMAGED	PEST	PAGE
Pines, Two-or Three-Needled		**Abiotic Injuries**	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (on seedlings)	9
		Douglas-fir Tussock Moth (occas. ponderosa pine)	13
		Pine Needle Sheathminer (lodgepole and ponderosa pine)	21
		Spruce Budworm (occas.)	23
		Western False Hemlock Looper (occas. ponderosa pine)	27
		Diseases	
		Elytroderma Disease (lodgepole and ponderosa pine)	99
		Pine Needle Cast (lodgepole pine)	105
		Red Band Needle Disease	107
		Abiotic Injuries	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/ Winter Kill	145
	Main Stem or Branches	**Insects**	
		Giant Conifer Aphid	37
		Northern Pitch Twig Moth	47
		Diseases	
		Atropellis Canker	61
		Comandra Blister Rust	69

HOST	PART OF TREE DAMAGED	PEST	PAGE
Pines, Two-or Three-Needled		Hemlock Dwarf Mistletoe (lodgepole pine, coastal, rare)	87
		Larch Dwarf Mistletoe (occas., lodgepole pine)	89
		Lodgepole Pine Dwarf Mistletoe	91
		Orange Stalactiform Blister Rust (lodgepole pine)	71
		Sweet-fern Blister Rust	69
		Sydowia Tip Dieback	65
		Western Gall Rust	73
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Insects**	
		Warren's Root Collar Weevil (lodgepole pine)	49
		Diseases	
		Armillaria Root Disease	117
		Black Stain Root Disease (lodgepole pine, interior)	119
		Laminated Root Rot (occas.)	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163

HOST	PART OF TREE DAMAGED	PEST	PAGE
Spruce Sitka, Engelmann, White, or Black Spruce	Branch Tips or Leaders	**Insects**	
		Cooley Spruce Gall Adelgid	35
		White Pine Weevil	51
		Diseases	
		Sirococcus Tip Blight	109
		Abiotic Injuries	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (white spruce, other spruce species occas., on seedlings)	9
		Bud Moth	11
		Green Spruce Aphid	39
		Hemlock Sawfly (Sitka spruce)	15
		Spruce Budworm	23
		Western Blackheaded Budworm	25
		Western False Hemlock Looper (occas., Engelmann spruce)	27
		Diseases	
		Spruce Needle Cast	111
		Abiotic Injuries	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145
	Main Stem or Branches	**Insects**	
		Giant Conifer Aphid	37

HOST	PART OF TREE DAMAGED	PEST	PAGE
Spruce		**Diseases**	
		Douglas-fir Dwarf Mistletoe (occas., interior)	85
		Hemlock Dwarf Mistletoe (occas., Sitka spruce)	87
		Larch Dwarf Mistletoe (occas., interior)	89
		Lodgepole Pine Dwarf Mistletoe (rare, interior)	91
		Spruce Broom Rust	81
		Sydowia Tip Dieback	65
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Insects**	
		Conifer Seedling Weevil (Sitka spruce, on seedlings)	43
		Warren's Root Collar Weevil (Engelmann or white spruce)	49
		Diseases	
		Annosus Root Disease (Sitka spruce)	115
		Armillaria Root Disease	117
		Laminated Root Rot (occas.)	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163

HOST	PART OF TREE DAMAGED	PEST	PAGE
True Firs Grand, Amabilis, or Subalpine Fir	Branch Tips or Leaders	**Abiotic Injuries**	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (occas., on seedlings)	9
		Bud Moth (occas.)	11
		Hemlock Sawfly (amabilis fir)	15
		Spruce Budworm	23
		Western Blackheaded Budworm (amabilis or subalpine fir)	25
		Western False Hemlock Looper (occas., subalpine fir)	27
		Diseases	
		Fir-Fireweed Rust	101
		Abiotic Injuries	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145
	Main Stem or Branches	**Insects**	
		Balsam Woolly Adelgid	33
		Diseases	
		Douglas-fir Dwarf Mistletoe (grand fir, occas.)	85
		Fir Broom Rust	79
		Hemlock Dwarf Mistletoe (amabilis or grand fir, occas.)	87

HOST	PART OF TREE DAMAGED	PEST	PAGE
True Firs		Larch Dwarf Mistletoe (occas. subalpine or grand fir)	89
		Red Flag Disease	65
		Sydowia Tip Dieback	65
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Insects**	
		Conifer Seedling Weevil	43
		Diseases	
		Annosus Root Disease	115
		Armillaria Root Disease	117
		Laminated Root Rot	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163
Western Hemlock	Branch Tips or Leaders	**Diseases**	
		Sirococcus Tip Blight (on seedlings)	109
		Abiotic Injuries	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139

HOST	PART OF TREE DAMAGED	PEST	PAGE
Western Hemlock		**Animals**	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Black Army Cutworm (occas., on seedlings)	9
		Hemlock Sawfly	15
		Western Blackheaded Budworm	25
		Western False Hemlock Looper (occas.)	27
		Western Hemlock Looper	29
		Abiotic Injuries	
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145
	Main Stem or Branches	**Diseases**	
		Hemlock Dwarf Mistletoe	87
		Phomopsis Canker (occas.)	63
		Sydowia Tip Dieback	65
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163

HOST	PART OF TREE DAMAGED	PEST	PAGE
Western Hemlock	Roots or Root Collar	**Insects**	
		Conifer Seedling Weevil	43
		Diseases	
		Annosus Root Disease	115
		Armillaria Root Disease	117
		Black Stain Root Disease	119
		Laminated Root Rot	121
		Rhizina Root Disease (occas., on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163
Western Red Cedar	Branch Tips or Leaders	**Abiotic Injuries**	
		Drought	133
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Animals	
		American Porcupine (occas.)	153
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Foliage	**Insects**	
		Western Hemlock Looper	29
		Diseases	
		Cedar Leaf Blight	95
		Abiotic Injuries	
		Cedar Flagging	131
		Drought	133
		Fume Damage	137
		Ice/Snow/Hail Damage	139
		Nutrient Deficiencies	143
		Red Belt/Winter Kill	145

HOST	PART OF TREE DAMAGED	PEST	PAGE
Western Red Cedar	Main Stem or Branches	**Diseases**	
		Phomopsis Canker (occas.)	63
		Sydowia Tip Dieback	65
		Abiotic Injuries	
		Frost Injury	135
		Ice/Snow/Hail Damage	139
		Mechanical Damage	141
		Sunscald (occas.)	147
		Windthrow	149
		Animals	
		American Porcupine (occas.)	153
		Black Bear/Grizzly Bear	155
		Deer	157
		Snowshoe Hare/Cottontail Rabbit	159
		Tree Squirrel	161
		Vole	163
	Roots or Root Collar	**Insects**	
		Conifer Seedling Weevil (occas.)	43
		Diseases	
		Annosus Root Disease	115
		Armillaria Root Disease	117
		Laminated Root Rot (occas., interior only)	121
		Rhizina Root Disease (on seedlings)	123
		Tomentosus Root Rot	125
		Animals	
		Vole	163

SPECIMEN COLLECTION AND SHIPMENT

Reporting the incidence of insect, disease, abiotic or animal related damage is important to protect British Columbia's forests. Specimens should always be forwarded to specialists, particularly when positive identification is in doubt. To facilitate identification, the following procedure should be used:

- Name, address and telephone number of collector.
- Date and location specimen collected. Use block or lot number, geographic location name, etc.
- Host species, age and notes on general appearance.
- A general description of the area, especially any information you think may be related to the problem. Give your opinion concerning the identity of the problem.
- Collect sufficient material that adequately illustrates both symptoms and signs.
- Pack specimens properly and mail promptly as outlined below.

Proper collection and shipment of specimens is of paramount importance for their subsequent identification. Use the following guideines:

- Materials such as foliage, bark, fruiting bodies and sections of roots or wood should be wrapped in newspaper or paper bags and then placed in a box for mailing. Do not use plastic wrapping, since this encourages excessive moisture, mold growth and subsequent deterioration.
- Insect specimens such as larvae, pupae, sucking insects and weevils should be placed in leak-proof bottles or vials containing a sufficient amount of 70% or more concentrated isopropyl (rubbing) alcohol. Moths and butterflies should be killed without liquid. Use 140° F or freezing temperatures for 15 minutes in order to kill specimens, then place samples in a flat position between paper and pack in a box. If quick delivery can be assured, collect additional live specimens along with sufficient host material for rearing.
- All specimens and materials should be packed to endure rough handling. Use a sturdy shipping box and add sufficient packing material, such as styrofoam chips or paper, to prevent movement and breakage. Mark "FRAGILE: SCIENTIFIC SPECIMENS ENCLOSED" on the box.
- Include the written statement of observations as previously described.
- Mail specimens as soon as possible after collection in order to minimize deterioration. Store samples in a refrigerator if any shipping delay cannot be avoided. Keep some duplicate specimens for future reference since submissions will not be returned.

Mail samples to the following addresses, depending upon the region in which they were collected. B.C. Forest Service personnel should send specimens to the regional protection officer.

Forest Insect and Disease Survey,
Forestry Canada,
Pacific Forestry Centre,
506 West Burnside Road,
Victoria, B.C. V8Z 1M5

Protection Officer,
Ministry of Forests,
Vancouver Forest Region,
4595 Canada Way,
Burnaby, B.C. V5G 4L9

Protection Officer,
Ministry of Forests,
Kamloops Forest Region,
515 Columbia Street,
Kamloops, B.C. V2C 2T7

Protection Officer,
Ministry of Forests,
Nelson Forest Region,
518 Lake Street,
Nelson, B.C. V1L 4C6

Protection Officer,
Ministry of Forests,
Cariboo Forest Region,
540 Borland Street,
Williams Lake, B.C. V2G 1R8

Protection Officer,
Ministry of Forests,
Prince Rupert Forest Region,
3726 Alfred Ave.,
Smithers, B.C. V0J 2N0

Protection Officer,
Ministry of Forests,
Prince George Forest Region,
1011 - 4th Avenue,
Prince George, B.C. V2L 3H9

GLOSSARY

ABDOMEN - Posterior part of an insect's main body divisions.

ABIOTIC - Non-living.

ADVENTITIOUS - Arising in other than the usual location.

AERIAL SHOOT - Stem-like portion of a dwarf mistletoe parasitic plant that is outside the host bark. This portion produces sticky seeds.

ALTERNATE HOST - One of two or more different hosts required by an insect, fungus or other organism to complete its life cycle.

ANNUAL - A plant for which the entire life cycle is completed in a single growing season.

BASAL CUP - The cup-like remnant of a dwarf mistletoe infection remaining on the bark long after the disintegration of an aerial shoot.

BLIGHT - The sudden dying of shoots or foliage due to infection by certain species of blight fungi (or, rarely, by other microorganisms).

CAMBIUM - The actively dividing layer of cells which produces the conducting tissue of a vascular plant, therefore increasing the girth of a stem, branch or trunk.

CANKER - Dead portion of the cambium and bark on a branch or the main stem. Cankers can be raised or sunken and are sometimes surrounded by a raised lip of tissue.

CASE - The hollowed-out and silk-lined portion of a needle used as a protective covering by the larch casebearer.

CHLOROSIS - The yellowing of normally green foliage tissue due to lack of chlorophyll.

COCOON - Silken case spun by an insect larva inside which the pupa is formed.

CONDUCTIVE TISSUE - Refers to the xylem and/or phloem tissue of vascular plants through which the products of photosynthesis, water and nutrients are conducted.

CONK - The fruiting body of a wood decay fungus; bracket-like or resupinate but not a mushroom. Usually woody or leathery in texture.

DECAY - The gradual disintegration of plant tissue due to the action of wood destroying fungi and other microorganisms.

DIEBACK - The progressive dying from the tips downward or inward of shoots, twigs, tops, branches or roots.

DISTAL - Near or toward the free end of an appendage; that part of an appendage farthest from the body.

DISTRESS CROP - A crop of small cones produced by a tree under conditions of severe stress.

ENDEMIC - A disease, insect or vertebrate animal which is permanently established and occurs with little variation in severity or population level within a particular area.

EPIDEMIC - A widespread and unusually high level of incidence of a disease or insect pest; generally preceded by a rapid increase in population size.

EPIDERMIS - The outer tissue layer of leaves, young stems or roots.

FASCICLE - Attachment point for needle bundles on coniferous species.

FIVE-NEEDLED PINES - Pine species that have needles arranged in bundles of five. Sometimes loosely referred to as soft pines.

FLAGGING - Conspicuous dead shoots or branches with foliage still present but discolored.

FRASS - Solid excrement of insects, particularly larvae.

FRUITING BODY (or FRUITING STRUCTURE) - The reproductive structure of a fungus that produces spores.

FUNGUS (Pl. FUNGI) - A group of lower organisms that usually reproduce by spores and are composed of cellular filaments (hyphae). Fungi obtain their nutrients from other organisms.Most conifer diseases are caused by fungi.

GALL - An abnormal growth of plant tissue seen as a swelling on the branches or main stem and caused by fungal or insect activity.

HIP CANKER - With respect to western gall rust, an old gall that forms a canker-like lesion with a flattened face and bulging sides on one side of the main stem.

HYPHA (Pl. HYPHAE) - A fine, usually branched, threadlike filament of the vegetative body of a fungus that grows on or within the host. A bundle of hyphae is termed a mycelium.

INCIPIENT - An early, less noticeable or hidden stage in the progression of a disease or disorder.

INCISOR - A tooth adapted for cutting.

INFECTION - The entry of an organism or virus into a host and the establishment of a pathogenic or parasitic relationship.

INSTAR - A stage in the development of an insect larva between periods when the larva sheds its skin in order to grow.

INTERNAL RADIAL SHAKE - The internal radial cracking of wood due to expansion and contraction as a result of frost.

LAMINATED - Separated into layers or sheets, particularly along the annual rings.

LARVA (Pl. LARVAE) - An immature form of an insect that undergoes complete metamorphosis.

LESION - A localized area of dead or diseased tissue.

LION'S TAIL - With respect to Elytroderma disease, a severe infection resulting in so much needle casting that only the current needles remain on the branchlets, thus creating a tufted appearance.

LOOPER - Larval stages of some Lepidoptera which have some of the abdominal legs missing, thus causing the back to arch when moving.

MYCELIUM (Pl. MYCELIA) - The vegetative feeding structure of a fungus, composed of interwoven hyphae, and considered distinct from the fruiting body.

NECROSIS (NECROTIC) - Death of cells or tissues which are still part of a living organism.

NEEDLE CAST - Premature dropping of needles due to attack by certain needle cast fungi or occasionally caused by non-infectious organisms.

NUTRIENT - An element required to maintain health and normal growth.

NYMPH - Immature stage of an insect which undergoes incomplete metamorphosis; resembles the adult except for incomplete gonad and wing development.

PATHOGEN - A living organism that incites disease in a host.

PERENNIAL - A woody or herbaceous plant that lives from year to year and does not die after flowering once.

PEST - Any organism considered detrimental to effective forest management.

PHLOEM - One of the conducting tissues of vascular plants through which products of photosynthesis are transported; located adjacent to the cambium or inner bark.

PRIMARY HOST - The organism on which the first two stages of a rust fungus exist.

PUPA (Pl. PUPAE) - The inactive transitional stage in insects between the larva and adult portions of the life cycle. This stage is characterized by a protective covering formed by a larva during pupation.

PUPATION - Transition of an insect larva into a pupa and subsequent development within the pupa.

PUSTULE - An immature fruiting body on the host exterior, either button-like or blistered in appearance.

RESINOSIS - An abnormal flow of resin or pitch from a conifer usually in response to infection, insect activity or wounding.

RESISTANT - The ability to withstand attack by pathogens or insects.

RESUPINATE - A fruiting body that is reclined or flat on the host or ground.

RHIZOMORPH - A dark, hardened, cordlike structure made of hyphae occurring in some fungi, e.g. *Armillaria* spp.

ROOT BALL - The characteristic pattern of roots rotted off close to the root collar as seen in toppled trees with root disease.

ROT - A state of wood decay which is usually obvious and is generally caused by fungal attack.

RUST - A disease caused by infection with one of the rust fungi, often producing brown to red spores at some point during the infection.

SECONDARY ATTACK - Attack by those organisms which only invade hosts predisposed by stress or attack by more virulent or aggressive organisms.

SENESCENCE - The process of aging.

SIGN - Visible portion of a pest, such as a conk or frass, seen on, in or around the host.

SHEPHERD'S CROOK - Bending of the leader to form an inverted j-shape. An early indicator of weevil attack.

SPIKE-TOP - The dead portion of the upper crown or a dead leader devoid of any foliage.

SPORE - A microscopic reproductive structure of fungi and lower plants consisting of one or several cells.

SPOROPHORE - The fruiting body of a fungus that produces spores, e.g. conk or mushroom.

SYMPTOM - Visible reaction of a host to abiotic injuries or pest attack, e.g. chlorosis.

TARGET CANKER - A perennial canker distinguished by concentrically arranged zones of callus which mark alternate out-growth and death of the edge of living tissues surrounding the wound.

TUSSOCK - A brush-like protruding bundle of hairs. Seen especially on Douglas-fir tussock moth larvae.

TWO- OR THREE-NEEDLED PINES - Pine species that have the needles arranged in bundles of two or three. Sometimes loosely referred to as hard pines.

VECTOR - Any living or non-living agent that can carry a pathogen from one host to another.

WEEVIL - A beetle of the family Curculionidae, characterized by a head prolonged into a beak or snout and bearing clubbed, elbowed antennae.

WITCHES' BROOM - Abnormal proliferation of shoots or branches, usually induced by dwarf mistletoe, rust fungi or other organisms but sometimes a response to abiotic agents.

XYLEM - The principal strengthening and water conducting tissue in most plants.

ZONE LINE - Narrow brown to black lines in decayed wood formed by fungi to resist invasion by other fungal species.

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Dr. R. Smith, Forestry Canada, Pacific Forestry Centre: Figure 115.
Dr. T. Sullivan, Mammal Pest Research Institute: Figures 213,220.
Dr. J. Sutherland, Forestry Canada, Pacific Forestry Centre: Figures 87,183.

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